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FEASIBILITY STUDY

FOR

REHABILITATION OF FOREST LAKE

PALMER, MASSACHUSETTS

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For your review &
Comments
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CULLINAN ENGINEERING CO., INC.
AUBURN - BOSTON, MASSACHUSETTS
CIVIL ENGINEERS — LAND SURVEYORS

LAKES

FEASIBILITY STUDY

FOR

REHABILITATION OF FOREST LAKE

PALMER, MASSACHUSETTS

DECEMBER 1981

TO

COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING
DIVISION OF WATERWAYS
BOSTON, MASSACHUSETTS

COMMONWEALTH OF MASSACHUSETTS RICHARD M. COX No. 20679 REGISTERED PROFESSIONAL ENGINEER

Richard M. Cox, PE
Project Engineer

Mark W. Popham
Environmental Engineer

PREPARED BY

CULLINAN ENGINEERING CO., INC.
CIVIL ENGINEERS/ENVIRONMENTAL CONSULTANTS/LAND SURVEYORS
AUBURN & BOSTON, MASSACHUSETTS

FOREST LAKE FEASIBILITY STUDY

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MASSACHUSETTS DIVISION OF WATER POLLUTION CONTROL

TECHNICAL SERVICES BRANCH

WESTVIEW BLDG., LYMAN SCHOOL

ROUTE 9, WESTBOROUGH, MASSACHUSETTS 01581

ROUTING AND TRANSMITTAL SLIP

TO: Al

FROM: Russ

DATE: 8/5/82

- [ ] Information requested
- [ ] For appropriate action
- [ ] Please reply
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- [ ] For your information
- [ ] For your file
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REMARKS: would like some one in lakes to review this and see how close it comes to fulfilling requirements required in draft 628 guidance. Also, do we have any data on Forest Lake + if so, how does it compare?

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INTRODUCTION

1. Background and Purpose of Study

In accordance with Contract No. 2957 for the Commonwealth of Massachusetts Department of Environmental Quality Engineering (DEQE), Division of Waterways, Cullinan Engineering Co., Inc., commenced an engineering feasibility study for rehabilitation of Forest Lake, Palmer, Massachusetts, in September 1980. Forest Lake, a 50-acre enlarged Great Pond in the Chicopee River basin, is choked with aquatic weed growth over a large part of the pond surface during the warmer months of the year. This extensive weed growth and generally shallow water depth have created aesthetically-unpleasing conditions for recreational users of the pond having informal access along Town roadways and for residential property owners who occupy a majority of its developable shoreline. The primary purpose of this Study is to investigate present conditions, assess the feasibility of physically modifying the present impoundment and/or watershed conditions to improve recreational - conservation use and formulate alternative rehabilitation measures in consideration of engineering, economic and environmental criteria.

2. Study Approach

Completion of the Study and preparation of this report have been conducted in accordance with the Scope of Work items described in the Division of Waterways (MDOW) Contract. The principal aspects addressed herein are as follows:

1) Prepare a detailed review of all available data, including Town and regional plans; engineering/planning reports and studies; applicable Town, Commonwealth and Federal regulations; as well as biological, natural resources and environmental reports and surveys;

2) Conduct field investigations necessary to verify and supplement data on existing conditions, establish planning/engineering criteria and determine site characteristics;

3) Determine sources of pollution to Forest Lake and its watershed, including tributary streams, surface drains and subsurface sewage disposal systems;

4) Evaluate the impact of nutrient inputs on the overall water quality and eutrophication status;

5) Collect and analyze sediment samples to determine the potential environmental/ public health impacts and costs of sediment disposal or use alternatives and feasibility of various alternatives, based upon assessment of horizontal and vertical variations in sediment cores and analyses of physical and chemical characteristics of the sediment;

6) Develop nutrient and hydrologic budgets;

7) Identify aquatic vegetation types and distributions;

8) Consult with interested Town and Commonwealth officials and agents during the Study and attend public information meetings, as necessary;

9) Address requirements for diagnostic - feasibility studies as prescribed by the U.S. Environmental Protection Agency (EPA) (Region I) Section 314, Clean Lakes Program and Final Application Form of the Massachusetts Eutrophication and Aquatic Vegetation Control Program; and,

10) Prepare a report addressing the aforementioned aspects.

Reitzel Associates, a Commonwealth/EPA-certified laboratory, of Boylston, Massachusetts, has assisted in the determination of water quality in Forest Lake and its tributary streams and the physical/ chemical characteristics of bottom sediment.

3. Previous Reports, Planning/Analysis Criteria and Related State/Federal Programs

Land use, water supply, water quality management and other planning materials prepared through the programs of the Lower Pioneer Valley Regional Planning Commission (LPVRPC), West Springfield, were consulted for assessment of present conditions in the Study area and development of criteria for improvements planning. Hydrologic investigations, water quality studies and management plans of the Commonwealth's Water Resources Commission (MWRC) and its departments aided in evaluation of lake characteristics and recommendation of environmentally-sound rehabilitation measures. Reportings of the U.S. Department of the Interior Geological Survey (USGS), U.S. Department of Agriculture Soil Conservation Service (SCS), U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers and Federal Emergency Management Agency (FEMA) have been utilized as guidelines for developing and analyzing rehabilitation alternatives. Applicable environmental regulations and guidelines have been consulted for recommendation of the most feasible approach.

APPENDIX A of this report lists those studies, reports and other materials which have provided input toward completion of the Forest Lake Feasibility Study.

SECTION II

DIAGNOSTIC STUDY:
FOREST LAKE & ITS WATERSHED - PAST, PRESENT & FUTURE

SECTION II

DIAGNOSTIC STUDY: FOREST LAKE & ITS WATERSHED - PAST, PRESENT & FUTURE

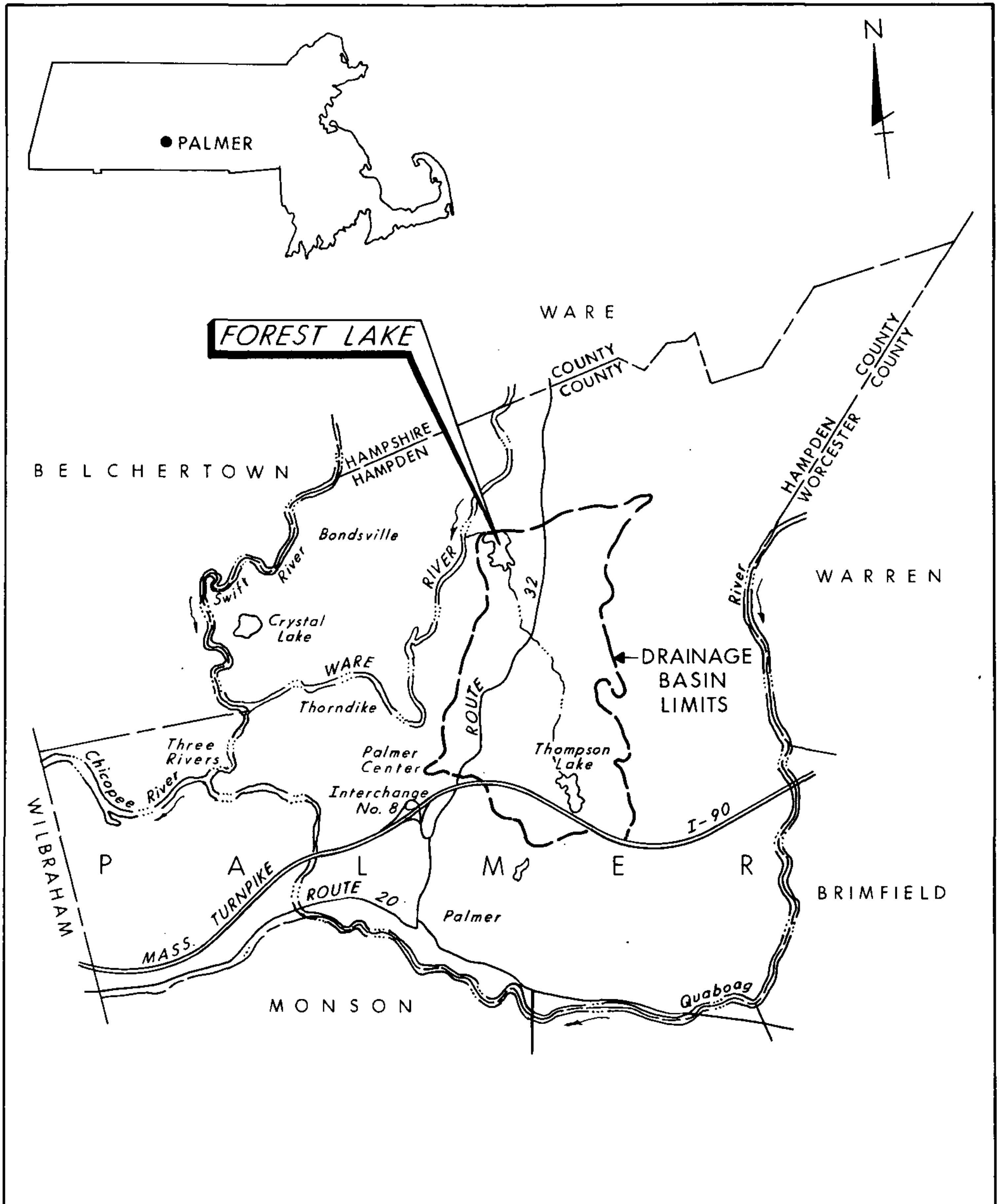
1. Identification/Location of Lake

Forest Lake and its tributary watershed are entirely located in the Town of Palmer, Massachusetts, in north-central Hampden County, with a latitude of 42° 12' 26.5" and longitude of 42° 18' 30" at the center of the Lake. Situated less than four miles from Interchange 8 of the east-west Massachusetts Turnpike (Interstate I-90), the Lake is approximately 18 miles from Springfield, 28 miles from Worcester, 70 miles from Boston and 38 miles from Hartford, Connecticut.

FIGURE 1 depicts the general location of Forest Lake, its watershed, key nearby water resources and highways.

Forest Lake has only one non-seasonal, unnamed tributary. Forest Lake and its upland watershed lie within the drainage basin of the Chicopee River. Outflow from Forest Lake flows 100 feet to the Ware River approximately 4.4 miles upstream of its confluence with the Swift River and 5.2 miles upstream of its confluence with the Quaboag River. The confluence of the Ware River, the Swift River and the Quaboag River at the village of Three Rivers in Palmer forms the headwaters of the Chicopee River. The Chicopee River reaches the Connecticut River in Springfield, flowing eventually to Long Island Sound.

Forest Lake, its tributary and receiving waters maintain a Massachusetts Class B, "fishable/swimmable", ranking.



LOCATION MAP

FOREST LAKE — PALMER, MASSACHUSETTS

FIGURE 1

2. Geological and Soils Description of Drainage Basin

A. Geological Description - The predominant bedrock types within the Palmer area of Massachusetts are igneous and sedimentary, as identified by the "Preliminary Geologic Map of Massachusetts and Rhode Island" developed by USGS in 1916. The sedimentary rock is primarily a Brimfield schist - a "rusty" graphitic biotite schist.

The predominant igneous rock that underlies the majority of the Forest Lake watershed is Dana diorite. This diorite is a combination of diorite with diorite schist and diorite aplite or ribbon gneiss. The most abundant elements within this formation are oxygen, silicon, aluminum, calcium, iron, sodium, potassium and magnesium.

B. Groundwater Hydrology and Water Supply - The USGS, in cooperation with the U.S. Army Corps of Engineers (USACE), has determined that a majority of the Forest Lake watershed lies within an aquifer area generally favorable for development of 0.5 million gallons-per-day (mgd) of groundwater per well in ice-contact and valley-train deposits. A 110-foot deep well near the Ware River just north of Forest Lake was reported by USGS to yield greater than 100 gallons-per-minute (gpm). An estimated 70-foot deep 2-inch cased well at the State Fish Hatchery on Route 32 is reported by the Massachusetts Division of Fisheries and Wildlife (MDFW) to yield 350 gpm.

USDA, in cooperation with MWRC, reported in their 1978 regional resources inventory that the Town of Palmer presently has a 2.7 mgd safe yield municipal water supply derived from both surface water and groundwater resources.

The Lower Pioneer Valley Regional Planning Commission (LPVRPC) has reported water to be supplied by four private water utilities: the Bondsville Water Company, the Three Rivers Fire & Water District, the Thorndike Fire & Water District and the Palmer Fire District. Private water supply wells serve development around Forest Lake.

The Soil Conservation Service (SCS), in cooperation with MWRC in 1973, evaluated existing impoundments and potential reservoir sites in the Town of Palmer. Two potential sites in the Forest Lake watershed were on an unnamed brook, 1) about 200 feet upstream of Gates Road and, 2) about 1,850 feet upstream from Gates Road. Water supply development at these sites is severely limited by reportedly poor water-holding capabilities, location of overhead utilities, flooding of Gates Road and/or present quality of stormwater runoff from the Palmer Center-Burleigh Park Area. Expansion of Forest or Thompson Lakes was reportedly prohibitive due to the extent of abutting shoreline development.

C. Topography - Forest Lake's watershed is generally irregularly-contoured and variably sloping throughout. Compared to Forest Lake's mean surface elevation of 369 feet above mean sea level (MSL), prominent elevations include a portion of Pattaquattic Hill over 1,000 feet MSL in the far northeastern section of the drainage area, King's Mountain summit at elevation 705 feet MSL and an unnamed hilltop at 826 feet MSL northeast of Thompson Lake. An uncharacteristic gently-sloped plain occurs in the Whipples area just southeast of Forest Lake.

Slopes within the watershed vary from approximately 2 to 50 percent with an average slope of 8%. Slopes in the watershed are summarized as follows:

Percent Slope Range	Percent Watershed Area
less than 3%	5%
3-8%	30%
8-15%	30%
15-25%	25%
more than 25%	10%
	100%

D. Soils - The 1978 Soil Conservation Service (SCS) soil survey for central Hampden County indicates three (3) major soil associations in the Forest Lake watershed, described as follows:

Charlton-Woodbridge-Paxton: Comprising about 30 percent of the well-drained or moderately well-drained upland areas in the northeasterly portion of the watershed, this association is comprised of deep soils with a moderately coarse-textured or medium-textured surface layer and subsoil and a firm to friable substratum.

Narragansett-Charlton: This association of well-drained soils, similar to the Charlton-Woodbridge-Paxton group, covers about 40 percent of the westerly and southeasterly watershed areas.

Hinckley-Windsor-Merrimac: Excessively-drained soils on glacial outwash terraces, this association, which covers the remaining central part of the watershed, is made up of deep soils having a moderately coarse or coarse-textured surface layer and subsoil and a loose, coarse substratum.

Detailed SCS soils information covering the Forest Lake watershed was developed as part of the 1978 County soil survey. A description of each identified soil type is given as follows:

Charlton extremely stony fine sandy loam: This soil, found on 3-25% slopes, is deep and well drained principally formed in glacial till derived from mica schist, phyllite and gneiss. Commonly on the lower sides on hills and ridges, stones are scattered 5 to 20 feet apart on the surface. The surface layer is fine sandy loam about 3 to 4 inches thick. The subsoil is fine sandy loam 17 to 25 inches thick with the substratum of similar material to a depth of 60 inches. Permeability is moderate or moderately rapid and available water capacity is high. Erodability is variable depending on slope. This soil has poor potential for farming and for openland and wetland wildlife habitat; good potential for woodland; fair potential for woodland wildlife habitat; and poor potential for most urban uses or sanitary on-site systems.

Charlton and Narragansett extremely stony soils:

Found on 25-40% slopes in the Mason Street area, these soils are both deep and well drained, with stones scattered 5 to 20 feet apart on the surface. The typical surface layer is fine to very fine sandy loam to about 3 inches and similar subsoil 17 inches thick. The fine to very fine sandy loam subsoil extends to 60 inches. Permeability ranges from moderate to rapid. Erodability is moderate.

This soil has poor potential for farming and for openland and wetland habitat; good potential for urban uses on sanitary disposal due to slope, large stones and high permeability.

Charlton - rock - outcrop - Hollis complex: This complex is comprised of about 35% deep well-drained Charlton soils, 30% rock outcrop and 15% shallow, somewhat excessively-drained Hollis soils on 3-25% slopes primarily in the Mason Street and Stimpson Street areas. The outcrops are exposed granite and gneiss bedrock less than 100 feet apart. The soils in this complex have poor potential for most uses due to slope, shallow bedrock, moderate or moderately-rapid permeability and large stones. Low-to-moderate erodability prevails.

Hinckley loamy sand: Found throughout most the central part of the watershed on variable slopes, this soil is on glacial outwash deposits derived mainly from granite and gneiss. The surface layer is loamy sand between 3 and 5 inches thick, while the subsoil is gravelly, loamy sand 9 to 13 inches thick and substratum to a depth of 60 inches in alternate layers of sand and gravel. Permeability is very rapid and water capacity very low. The soil has poor potential for farming, woodland and wildlife habitat, principally due to droughtiness and rapid leaching of nutrients. Although the soil has few limitations for most urban uses, sanitary onsite disposal is hindered by the very rapid permeability. Erodability is slight.

Merrimac sandy loam: This deep and somewhat excessively-drained glacial outwash soil is found on slopes up to 15% adjacent to Forest Lake. The surface layer is sandy loam to a depth of 5 to 7 inches and subsoil gravelly sandy loam and gravelly sand about 15 inches deep. The substratum is gravelly sand to about 60 inches deep. Permeability is moderately rapid or rapid in the subsoil and rapid in the substratum, while available water capacity is moderate. The soil has poor to good potential for farming and upland wildlife

habitat. The soil is limited for sanitary on-site sewage disposal primarily due to excessive permeability. Erodability is slight.

Muck: Nearly level, very poorly-drained organic material deposits are scattered in depressions throughout the watershed. This soil is limited for all upland uses due to high water table and flooding potential.

Narragansett extremely stony very fine sandy loam: This deep, well-drained soil, with surface stones scattered 5 to 20 feet apart, is found on variably-sloped ridges and hills along the eastern shore of Thompson Lake and in the Breckinridge Street - I-90 area. Underlain by glacial till, the soil's surface layer is moderately-erodable very fine sandy loam 4 to 8 inches thick with similar subsoil about 20 inches thick. Substratum is sandy loam underlain by gravelly loam sand to a depth of 67 inches. Permeability is moderately rapid or rapid in the substratum. Available water capacity is high. Suited essentially for pasture and wildlife habitat, the soil is limited for most urban uses and on-site sewage disposal by surface boulders and the substratum's excessive permeability.

Ninigret fine sandy loam: A small deposit of this gently-sloping soil on glacial outwash terraces is found just easterly of the Forest Lake shoreline. Deep and moderately well-drained, permeability is moderately rapid in the subsoil and rapid in the substratum, while available water capacity is moderate. A seasonal high water table in the lower 12 inches of the sandy loam subsoil, as well as rapid permeability in the sand substratum, limit most urban uses and sanitary on-site systems. Erodability is low to moderate.

Paxton extremely stony fine sandy loam: Principally situated on the tops and sides of the drumlin south of Rondeau Street and east of Route 32, this deep, well-drained soil has stones scattered 5 to 20 feet apart on the surface. A six-inch surface layer is comprised of fine sandy loam, while the similar subsoil is 18 to 26 inches thick. The substratum to a depth of 60 inches is fine sandy loam. Permeability is moderate or moderately rapid in the subsoil and moderately slow or slow in the substratum, while erodability is slight to moderate. A perched water table in the lower subsoil for brief periods in winter and early spring serves to limit most land uses and subsurface sewage disposal, as do the large stones and relative impermeability of the substratum.

Ridgebury extremely stony sandy loam: This gently sloping, deep and poorly-drained soil is found scattered in small deposits throughout the eastern half of the Forest Lake watershed. A six-inch deep sandy loam surface layer with stones scattered 5 to 20 feet apart is underlain by 10 inches of sandy loam subsoil and 60 inches of very firm sandy loam substratum. Permeability is moderately or moderately rapid in the subsoil and moderately slow to very slow in the substratum. Available water capacity is very low. The soil has poor potential for most uses, due to highwater table, relative impermeability of the substratum, large stones and high susceptibility to frost action.

Rock outcrop - Holyoke complex: This complex of exposed basalt, conglomerate, sandstone, granite or gneiss bedrock and steep Holyoke soils is found on hills and ridges generally north of Warren Street. The permeability of the Holyoke soils is moderate, while available water capacity is very low. This soil complex is severely limited for most uses.

Sudbury fine sandy loam: Found principally along Forest Lake's southeastern shore, this nearly level to gently sloping soil is deep and moderately well-drained. The surface layer is slightly erodable fine sandy loam to 10 inches underlain by fine and gravelly sandy loam layers together 13 inches thick and 60 inches loose, gravelly-sand substratum. Permeability is moderately rapid to rapid with moderate available water capacity. With good potential for farming, woodland and upland wildlife habitat, this soil has poor potential for sanitary waste disposal due to seasonal high water table and excessive permeability of the substratum.

Wareham loamy sand: This nearly level, deep and poorly drained soil on sandy glacial outwash is scattered throughout the southern half of the watershed and along a portion of Forest Lake's eastern shore. The surface layer is about 10 inches of loamy sand underlain by up to 60 inches of loamy sand and sand. Permeability is rapid with moderate available water capacity. Erodability is slight. This soil is limited for urban uses and sanitary waste disposal facilities by seasonal high water table and rapid permeability.

Windsor loamy sand: Largely situated on variable slopes in the Palmer Center - Burleigh Park and Whipples areas, this excessively-drained soil is on glacial outwash terraces and plains. Surface layer, subsoil and substratum to a depth of 60 inches is loamy sand or sand. Permeability is rapid to very rapid with low available water capacity. The soil is poorly suited for most agricultural, forestry or wildlife habitat uses and subsurface sewage disposal is limited by excessive permeability.

Woodbridge extremely stony fine sandy loam: This variably sloped soil found on drumlins east and southeast of Forest Lake is deep and moderately well-drained. Stones are scattered 5 to 20 feet apart on the surface. The surface layer is several inches of fine sandy loam underlain by similar material subsoil and substratum to 60 inches. Permeability is moderate or moderately rapid in the subsoil and slow or moderately slow in the substratum, while available water capacity is moderate. A seasonal highwater table is in the lower subsoil, serving to limit most uses in conjunction with frost action potential, slow permeability of the substratum and stoniness. Erodability is slight.

The estimated present yearly sediment loading from soil erosion to Forest Lake has been quantified by using the Universal Soil Loss Equation and by estimating the proportion of the erosion (sediment) that actually reaches the Lake:

S = (Sd)x(k)x(A)x(R)x(K)x(LS)x(C)x(Pr)

S = sediment load to Forest Lake (metric tons/year)

Sd = sediment delivery ratio, expressing the proportion of eroded material that eventually becomes bottom sediment (i.e., flows into and remains in Forest Lake). Sd varies between 0.22 for a small 0.1 km^2 drainage area to 0.02 for a 750 km^2 drainage area; for the Forest Lake watershed, Sd = 0.10 (assumed).

k = dimensional constant = 224.2 (one ton/acre/year = 224.2 metric tons/km^2/year)

A = Forest Lake drainage area (km^2) = 9.11 km^2 (2,250 acres x .00405 km^2/acre)

R = rainfall factor = 150 for Hampden County (from SCS <u>Guidelines for Soil and Water Conservation in Urbanizing Areas of Massachusetts</u>, 1977, p. J-30).

K = soil erodability factor = 0.27 - estimated average soil erodability factor for soils within the Forest Lake watershed.

LS = factor combining length and degree of slope = 4.6 for estimated 8% slope and slope length of 2,300 feet (from SCS <u>Guidelines for Soil and Water Conservation in Urbanizing Areas of Massachusetts</u>, 1977, p. J-32).

C = erosion protection soil cover factor = 0.10 approximate composite for Forest Lake watershed land uses.

Pr = erosion control practice factor = 1.0 for nonagricultural areas.

$$S = (0.10)\times(224.2)\times(9.11)\times(150)\times(0.27)\times(4.6)\times(0.10)\times(1.0)$$

= 3,805 metric tons/year (3,460 tons/year)

= 3,075 lbs/acre/year

In summary, Forest Lake's watershed is dominated by sandy loam soil types, primarily Hinckley soils, which show a characteristic moderately-rapid permeability. A pervasive highwater table or excessive stoniness in conjunction with excessive permeability greatly limits the potential for subsurface sewage disposal within much of the watershed.

Soil erodability is moderate to low for a large majority of the contributing watershed. Excessively rapid permeability, seasonal highwater tables and the presence of ledge outcrops or stoniness serve to limit potential for such uses as agriculture and urban uses.

3. Public Access Description

No formal public access has been developed at Forest Lake. However, through its identification by MDOW as an enlarged Great Pond, public access is inherently provided for. Informal access is provided along approximately 1,600 linear feet of Bennett and River Streets at the northerly end of the main basin, including a small, unsupervised private beach area. Other access to the Lake is available at privately-owned Forest Lake Resort pavilion and to the smaller northern basin across a publicly-owned right-of-way.

Forest Lake is readily accessible by north-south State Route 32 and east-west Massachusetts Turnpike (Interstate I-90) and State Route 20. Public transportation access to Forest Lake is presently unavailable.

4. Population/Socio-Economic Structure

An approximate population of over 2,500,000 resides within an 80 km (50 mile) radius of Forest Lake. The major population centers within this radius include the Springfield and Worcester metropolitan areas in Massachusetts and part of the greater Hartford metropolitan area in Connecticut.

Population and economic data on the Town of Palmer and Hampden County since 1960 given by Massachusetts and Federal census results is given as follows:

Year	Population Palmer	% Change in prior 10-year period	Population Hampden County	% Change in prior 10-year period
1960	10,358	--	426,719	--
1965	10,394	--	-------	--
1970	11,680	12.8	459,050	7.6
1975	11,700	13.2	454,050	--
1980	11,410	-2.3	442,884	-3.5

Per Capita Income	Palmer	Hampden County
1970	$3,128	$2,878

Per Capita Tax Levy	Palmer	Hampden County
1980	$ 331.73	$ 396.85

Although somewhat similar local and regional population growth levels have been projected by Lower Pioneer Valley Planning Commission within the next decade, substantial future development in the Forest Lake watershed is limited by physiographic constraints, economic considerations and the attendant need for extension of municipal services.

Palmer's economic stability has recently become more dependent on the Springfield urban area since a major fire in Bondsville in 1968 and recent manufacturing plant closings. Current local industry includes farming (dairy and livestock), logging and quarrying.

5. Historical Lake Uses

Available historical information about the uses of Forest Lake dates back to the early 1600's. According to a local historian, Nipmuc Indians encamped near the lake during the warm summer months for fishing in the Ware River. The Hampden County Registry of Deeds indicates erection of a grist mill and saw mill in the 1700's.

Forest Lake became accessible in the 1800's via construction of the nearby Boston and Albany Railroad from Springfield. Forest Lake was known by several names during this period - South Pattaquattic Pond, Newell's Pond and Forest Lake Gardens. The Lake was used for winter pickerel fishing and, in the summer months, perch and horned pout fishing. The only other recreational use reported during the early and mid-1800's was occasional summer camping.

In the late 1800's, some of the local land-owners formed the Forest Lake Company and created a resort on the northwesterly shore of the Lake. The resort, which catered principally to picnics and family gatherings, was first opened to the public in 1885 as Forest Lake Park and became one of the most popular resorts in the area, warranting the construction of a playhouse and stables. A pavilion, including a roller skating arena, ballroom and bowling alleys, and an amusement park, offering a merry-go-round, picnic area and slides, was also constructed. The pavilion has remained and is presently known as the Forest Lake Resort.

Swimming in Forest Lake increased and became the primary summer use of the Lake during the 1900's. Fishing has continued to be popular over the years; and, in recent years, motorboating on the Lake has also become a major use.

Reports dating back to 1901 describe the already existing problem of aquatic weed growth with photographs showing extensive water lily growth. The Town Deputy observed annual fish kills, as explained at that time, due to limited dissolved oxygen in the water. Over-fishing was also noted to be a major problem. To alleviate the over-fishing, the State began to overstock the Lake and even closed it to winter fishing in 1904 for three years.

Forest Lake is presently classified as a marginal trout pond, with the Massachusetts Division of Fisheries and Wildlife (MDF&W) stocking approximately 2,000 rainbow trout and a varying number of brown trout twice annually. About one-half of the rainbow trout stocked range from six to nine inches in length. TABLE 1 indicates Forest Lake's recorded stocking history. Fish species caught in addition to rainbow trout include largemouth bass and chain pickerel.

The Town of Palmer has recently enacted the following local by-law limiting the use of motorboats:

> "No person shall operate a power-propelled craft of more than ten (10) horespower nor in excess of ten (10) miles per hour on Forest Lake, Palmer, Massachusetts.
>
> Whoever violates the provisions of this by-law shall be punished by arrest without warrant or fines of not less than $20.00 nor more than $50.00.
>
> The provisions of this by-law shall be enforced by State Police, Local Police, Law Enforcement Officers of the Division of Natural Resources, the Division of Marine and Recreational Vehicles and Local Officials appointed to Water Patrol."

TABLE 1

FOREST LAKE STUDY

FOREST LAKE - FISH STOCKING HISTORY

Year	No. Stocked Rainbow Trout	Brown Trout	Total Weight (lbs.)
1980	2,000	2,500	1,989
1979	2,000	500	1,182
1978	2,500	200	1,850
1977	3,600	---	1,883
1976	2,400	---	1,050
1975	2,600	---	817
1974	800	300	600
1973	600	---	475
1972	600	---	390
1971	600	---	300
1970	600	---	300
	18,300	3,500	10,836

	No. Stocked	Year
Brook trout	533	1904 - 1926
Rainbow trout	2,000	1901 - 1904
Sebago salmon	1,000	1901
Largemouth black bass	2,335	1929 - 1932
Smallmouth black bass	30,250	1913 - 1944
Horned pout	25,402	1916 - 1950
White perch	17,550	1913 - 1950
Yellow Perch	2,551,665	1913 - 1951
Pickerel	956	1919 - 1950
Crappie	2,170	1923 - 1949
Shiners	75	1949
Sunfish	194	1928 - 1949
Catfish	400	1916
Smelt	2,005,500	1906 - 1919
Bluegills	2,814	1928 - 1932
Forage fish	2,000	1942
Pike perch	1,580,000	1904 - 1920
Miscellaneous	1,200	1946

6. Adverse Impacts on Lake Users

Continuation of Forest Lake's present condition or further degradation would adversely affect all who reside near or periodically use the lake for recreational purposes. Of the estimated thirty (30) residences in the immediate vicinity, six (6) are year-round homes. In addition, two (2) commercial enterprises located along the shoreline are somewhat dependent upon continued recreational use of the Lake. The Forest Lake resort has complained of, and probably suffers financially from, the summer macrophyte growth.

As weed growth increases during the months of July and August, recreational enjoyment of the Lake diminishes. It has been reported by local businesses that there is a recent marked decrease in swimming activity by mid-August.

7. Comparison of Lake Uses to Others in Region

There are an estimated 898 lakes and ponds within a 50-mile (80 km) radius of Forest Lake, of which about 526 are over ten (10) acres in size and 55 classified as Great Ponds of Massachusetts. Although there is an abundance of lakes and ponds in the area bounded by the Connecticut River to the west, the Route 2 corridor to the north, the Routes 52/290/190 corridor to the east and north-central Connecticut, Forest Lake is one of the most readily accessible from the Springfield urban area offering diversified potential for recreational use.

Twelve (12) other ponds with an area greater than one acre lie within Palmer, with Thompson Lake in Forest Lake's southerly watershed area being the largest at 32 acres. All these ponds are essentially restricted to public recreational use. Only Pattaquattic Pond (18 acres), just north of Forest Lake, is a Great Pond.

8. <u>Point Source Pollution Discharges</u>

There are presently no NPDES (National Pollutant Discharge Elimination System) point source pollution discharges to Forest Lake nor any of its tributary streams.

In the early 1970's, the upstream State Fish Hatchery filed an application for discharge permit to the U.S. Army Corps of Engineers (USACE) in accordance with the provisions of the Refuse Act. Subsequent to its filing, authority for such permits was transferred to the EPA. Operations at the hatchery were changed in the interim, thereby negating the need for an NPDES permit in accordance with EPA guidelines. At the time the State Hatchery originally filed the permit application to the USACE, 45,000 pounds of fish were annually produced. Annual production since 1970 has ranged between approximately 5,000 and 10,000 pounds of fish, resulting in probable reduction in waste loadings. Wastes from the hatchery operation are currently discharged to a series of lagoons. There is reportedly no discharge from the lagoons to surface waters.

9. <u>Watershed Land Use and Non-Point Pollutant Loadings</u>

A large majority of Forest Lake's contributing watershed is currently in non-managed forest or wetlands. Active agricultural use occupies large tracts on Rondeau and Warren Streets. Low-density residential use is concentrated at Thompson Lake and Palmer Center and extends along portions of Ware Road (Route 32), Flynt Street, Stimpson Street, Warren Street and the Forest Lake shore. Limited commercial use within the watershed includes a gravel - removal operation on Route 32, two restaurants on Bennett Street and Thorndike Mills retail outlet in Palmer Center. In addition to several miles of single-lane residential streets and Route 32, a 1.4-mile segment of the four-lane Massachusetts Turnpike lies within the drainage area.

TABLE 2 gives approximate acreages, percent of watershed and key pollutant loading estimates for principal land use types, based upon assumed pollutant accumulation factors developed through Section 208 areawide water quality management programs. Composite theoretical loadings for the non-wetland portion of the total drainage area are 133, 652, 16 and 6 mg/l of biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrogen and phosphorus, respectively. Theoretical loadings of nitrogen and phosphorus are significantly higher than any stormwater or tributary stream sampling results.

TABLE 2

FOREST LAKE STUDY
WATERSHED LAND USES AND NON-POINT POLLUTANT LOADINGS

Land Uses	Area (Acres)	Percent Watershed	Constituents	Estimated Pollutant Loading lbs/yrs)	Estimated Pollutant Loading (mg/l)
Agriculture:					
Cultivated (Crops)	230	9	BOD	5,256	101
			Total N	1,232	24
			Total P	71	1
			COD	22,174	426
Non-Cultivated (Livestock and Grazing	50	2	BOD	1,035	91
			Total N	279	25
			Total P	181	16
			COD	6,078	537
Low density residential	360	14	BOD	19,710	242
			Total N	1,840	23
			Total P	144	2
			COD	127,458	1565
Commercial	30	1	BOD	5,256	774
			Total N	378	56
			Total P	33	5
			COD	21,188	3122
Transportation	100	4	BOD	17,410	770
			Total N	1,281	57
			Total P	220	10
			COD	69,642	3078
Forest	1,100	44	BOD	7,367	30
			Total N	1,409	6
			Total P	1,922	8
			COD	30,107	121
Water/Wetlands:	630	26	N/A	N/A	N/A
Total	2,500	100%			

10. Baseline and Current Limnological Data

A. Morphometric and Hydrologic Characterization

Morphometric and theoretical hydrologic data useful in assessing water quality and rehabilitation measures is presented in TABLE 3.

FIGURE 2 delineates the extent of Forest Lake's watershed. FIGURE 3 locates water quality sampling stations and flow monitoring points. The following breakdown of subwatersheds has assisted in evaluation of nonpoint source estimating:

Location	Contributing drainage area (acres)	Percent total watershed
Thompson Lake outlet	260	10
Stream 500 feet south of Gates Street (sampling Sta. 1B)	950	38
Rte. 32 at Fish Hatchery (sampling Sta. 1A)	1,620	65
Southerly inlet (sampling Sta. 1)	2,000	80
Easterly inlet (sampling Sta. 2)	150	6
Other areas	350	14

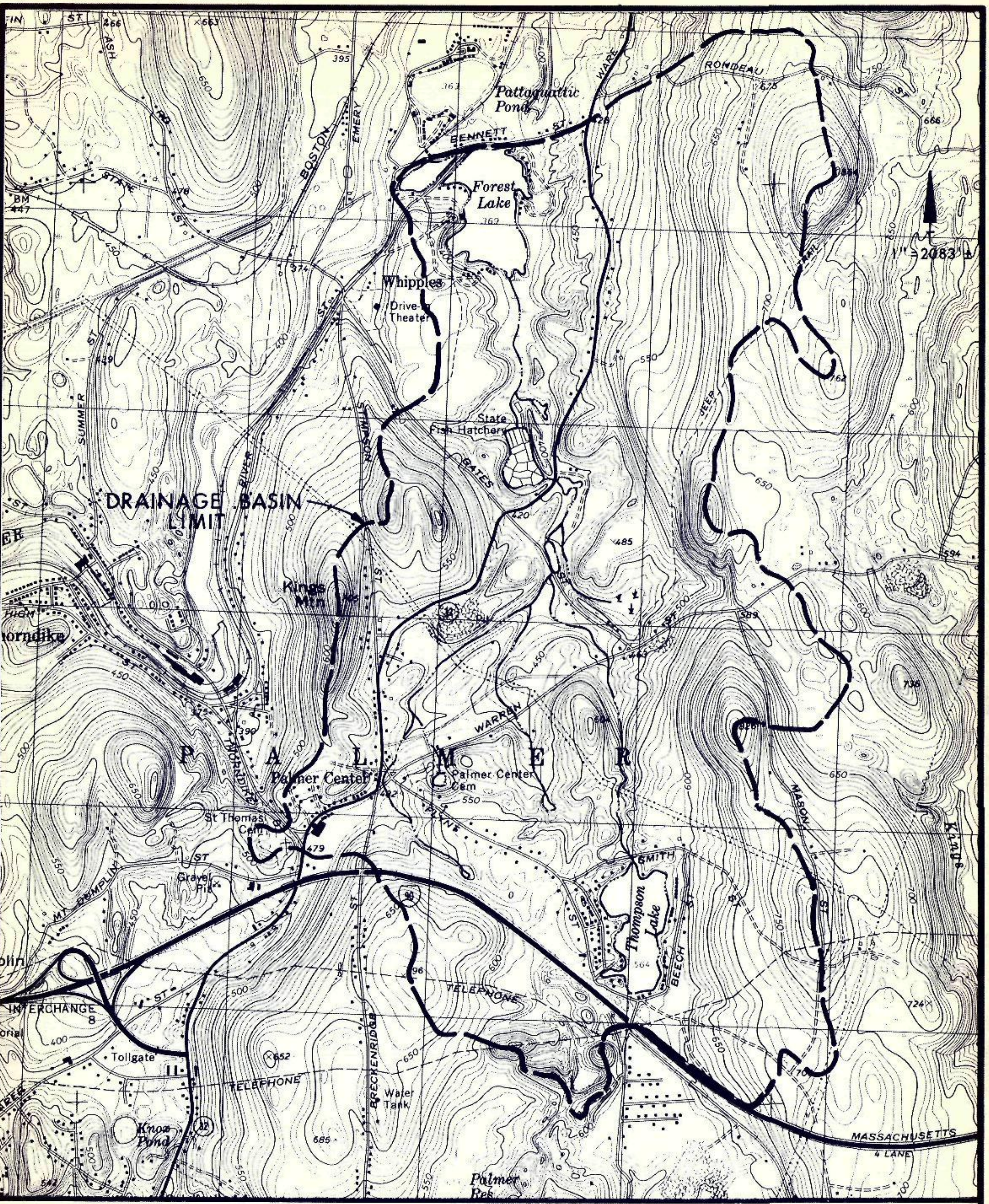
FIGURE 4 shows bathymetric information obtained during sediment investigations in February 1981.

Assessment of hydrologic data recorded for nearby river resources assists in the determination of a hydrologic budget for Forest Lake, as well as providing a basis for evaluating such possible rehabilitative measures as stormwater diversion and physical modification.

TABLE 3

FOREST LAKE STUDY
MORPHOMETRIC/HYDROLOGIC DATA

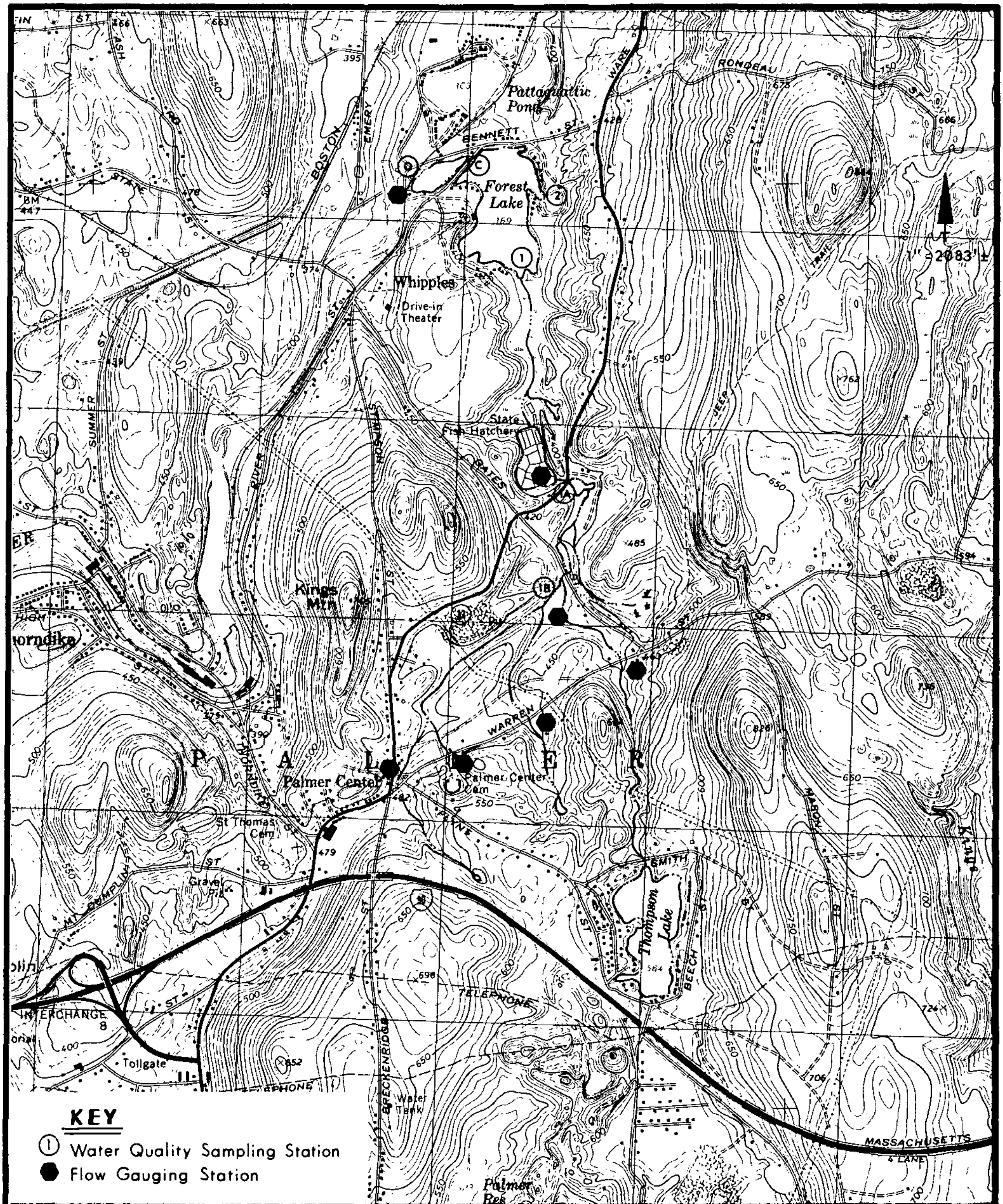
Maximum length	2,250 feet
Maximum width	2,165 feet
Maximum depth	26 feet
Mean depth	10 feet
Mean width	1,413 feet
Surface area (main basin)	44 acres
Drainage area	2,500 acres
Volume	450 acre - ft.
Runoff	21.7 in./yr.
Outflow	6 cfs
Flushing rate	19 times/yr.
Average residence time	19 days
Shoreline length	11,000 feet
Developed shoreline length	2,700 feet
Mean to maximum depth ratio	



DRAINAGE BASIN MAP

FOREST LAKE — PALMER, MASSACHUSETTS

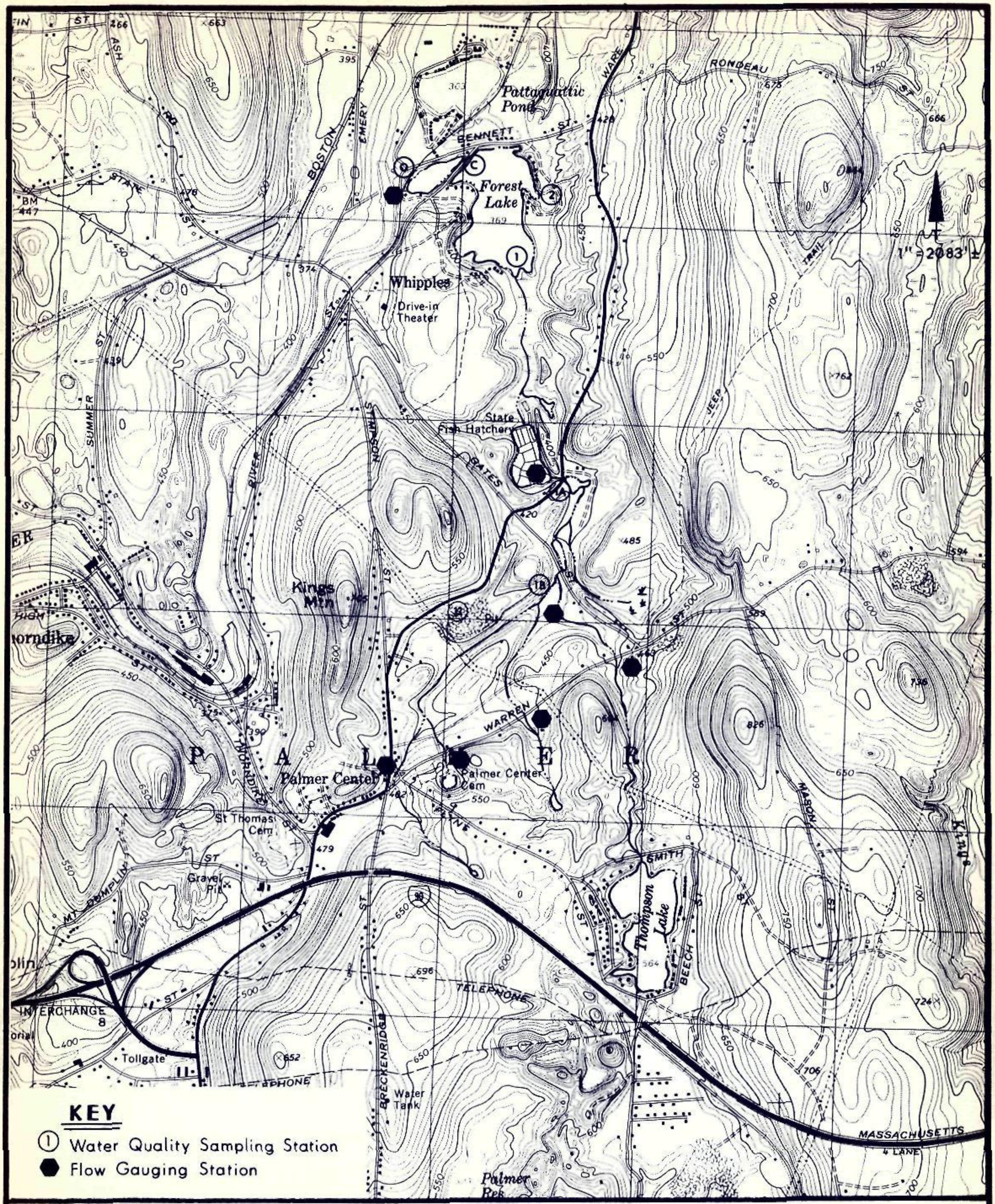
FIGURE 2



WATER QUALITY SAMPLING / FLOW GAUGING STATIONS

FOREST LAKE — PALMER, MASSACHUSETTS

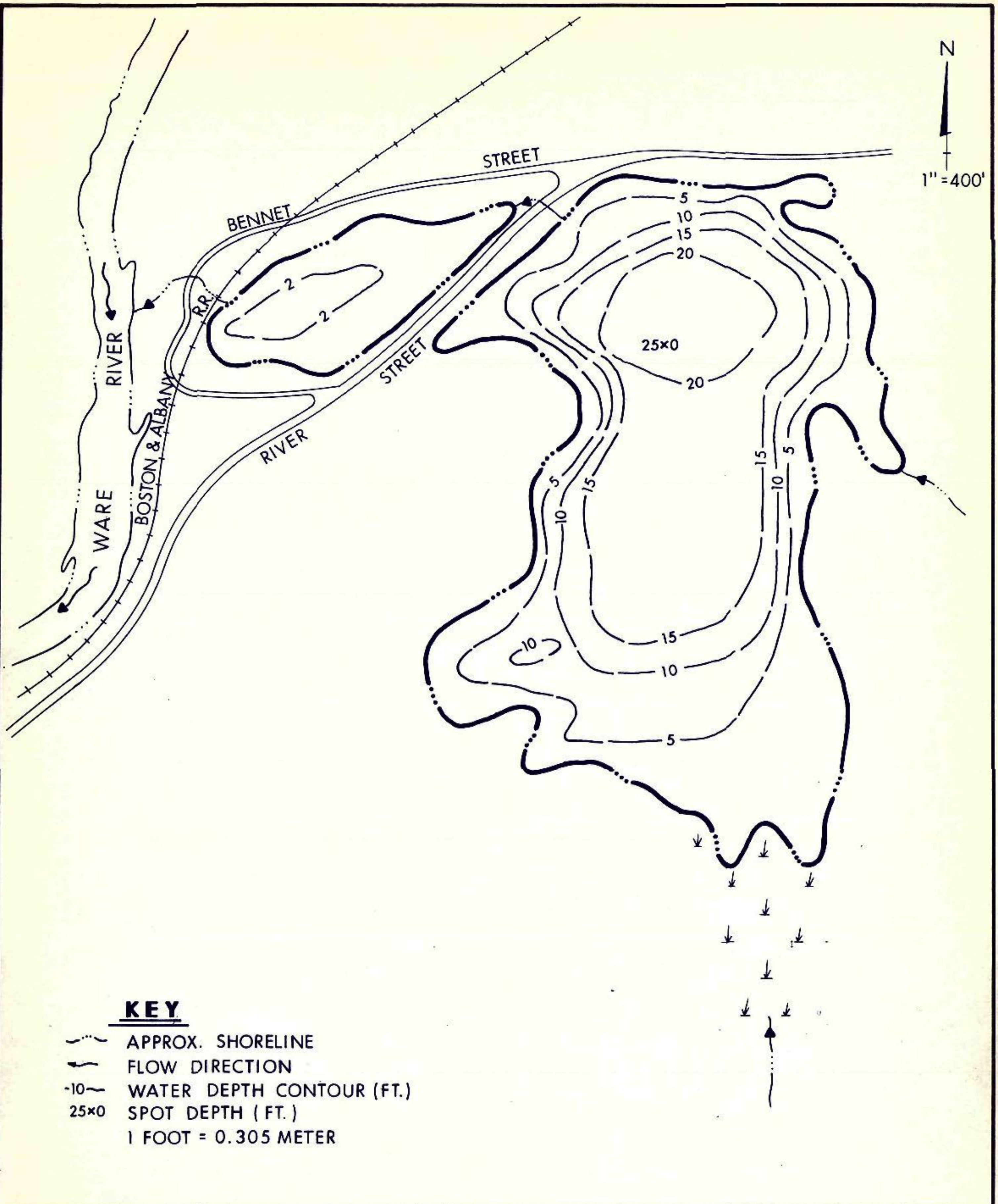
FIGURE 3



WATER QUALITY SAMPLING / FLOW GAUGING STATIONS

FOREST LAKE — PALMER, MASSACHUSETTS

FIGURE 3



BATHYMETRIC MAP
FOREST LAKE — PALMER, MASSACHUSETTS

FIGURE 4

USGS operates flow gauging stations at two sites within the vicinity of the Forest Lake watershed. One (01173500) is located on the Ware River near Gibbs Crossing, Ware, approximately 4.2 miles upstream of the Forest Lake outlet. The other USGS

Station (0117600) is situated on the Quaboag River in West Brimfield, about 3.2 miles southeasterly of Forest Lake. Average discharges for both sites over a number of years, accounting for storage and diversion effects, is 1.6 cfs per square-mile of drainage area. A minimum daily flow of 6 cfs has been recorded at the Ware River station. MDWPC has reported a seven-day, 10-year low flow at this station of 21.4 cfs.

Ware River stream flow is somewhat regulated by the U.S. Army Corps of Engineers' Barre Falls Dam, Barre, a 24,000 acre-foot flood control reservoir in operation since 1958 and the Metropolitan District Commission's Ware River water supply intake in Barre located four miles below the Dam.

A 1977 USACE flood plain information report indicated the flood of record (September, 1938) on the Ware River at Gibbs crossing to be 22,700 cfs. Peak flood flows attributed to the 100-, 50- and 10-year flood events were given as 25,000, 15,000 and 6,100 cfs, respectively, at the mouth of the Ware River. One-hundred year Ware River flood elevations of 379.1 and 374.5 feet MSL were given at the Boston & Maine railroad crossing and the Summer Street bridge, respectively. According to the USACE report, the 100-year flood, under existing conditions, would inundate private property and structures along portions of Bennett Street, River Street and the eastern Forest Lake shore. The 100-year flood would reportedly entail the overtopping of the Summer Street bridge, flooding of residential development around nearby Pattaquattic Pond and flooding of the tributary wetland along Forest Lake's southern shore.

The Federal Flood Insurance Administration's (FIA) Flood Hazard Boundary Map (1976) for the Town of Palmer identifies much of the previously described 100-year flood area as a special flood hazard area.

The Town of Palmer has reportedly recommended extension of this designated zone to include much of the State Fish Hatchery pool and reservoir area and a tributary wet area southwesterly of Gates Street.

An engineering consultant recently completing a Flood Insurance Study (FIS) for the Federal Emergency Management Agency (FEMA) in the Town of Palmer has preliminarily reported Ware River peak discharge values of 14,840, 10,850 and 5,000 cfs for the 100-, 50- and 10-year flood events, respectively, upstream of the Swift River confluence. Associated flood elevations have been given as follows:

	B&M R.R. Bridge	Summer Street Bridge
10-year	372.0	367.8
50-year	377.0	373.8
100-year	379.5	375.8

As previously indicated by USACE report, floodwaters of the 100-year storm would inundate a portion of Bennett Street at the Forest Lake causeway, adjacent residences/businesses and interspersed cottages along the shoreline.

The drainage area tributary to Forest Lake is currently an estimated 2,500 acres, somewhat modified from the natural watershed delineation by construction of roadways and appurtenant stormwater drainage works.

TABLE 4 summarizes estimated flow contributions from the two normally-flowing inlet streams, outflow and approximate groundwater contribution at sample collection dates. Forest Lake outflow averages 12 cfs over the year. Groundwater inflow accounts for 25 to 70 percent of the Lake's hydrologic budget and averages 55 percent.

A seven-feet high by eight-feet wide concrete box culvert in River Street (normally about four and one-half feet full) serves to equalize the main and minor basins. Outflow from the minor basin passes through a submerged stone culvert and a partly-filled 36-inch concrete culvert underlying the Conrail railroad fill, then falls approximately four feet vertically over a stone masonry spillway prior to culverting Bennett Street via a six-feet wide by five-feet high stone-masonry/concrete box culvert. A second concrete pipe culvert outlet exists but cannot pass flow due to excessive deposition of debris.

TABLE 4

FOREST LAKE STUDY
FLOW CONTRIBUTION ESTIMATES

Sampling Date	Southerly Inlet (1) (cfs)	Easterly Inlet (2) & Adjacent Areas (cfs)	Estimated Groundwater Contribution (%)	Forest Lake Outflow (cfs)
9/24/80	4	1	60	12
11/20/80	4	1	60	12
2/20/81	8	2	35	15
3/26/81	8	2	25	13
4/27/81	5	1	65	18
6/5/81	3	1	65	14
7/14/81	3	1	70	11
8/25/81	2	1	70	9

B. <u>Historical Baseline Data</u>

The only historical limnological data available dates back to 1914 when a transparency reading in the main body of water was reported to be 10.5 feet. Nuisance aquatic weed growth was reported predominantly in the smaller basin and, the northwestern and southeastern areas of the main basin.

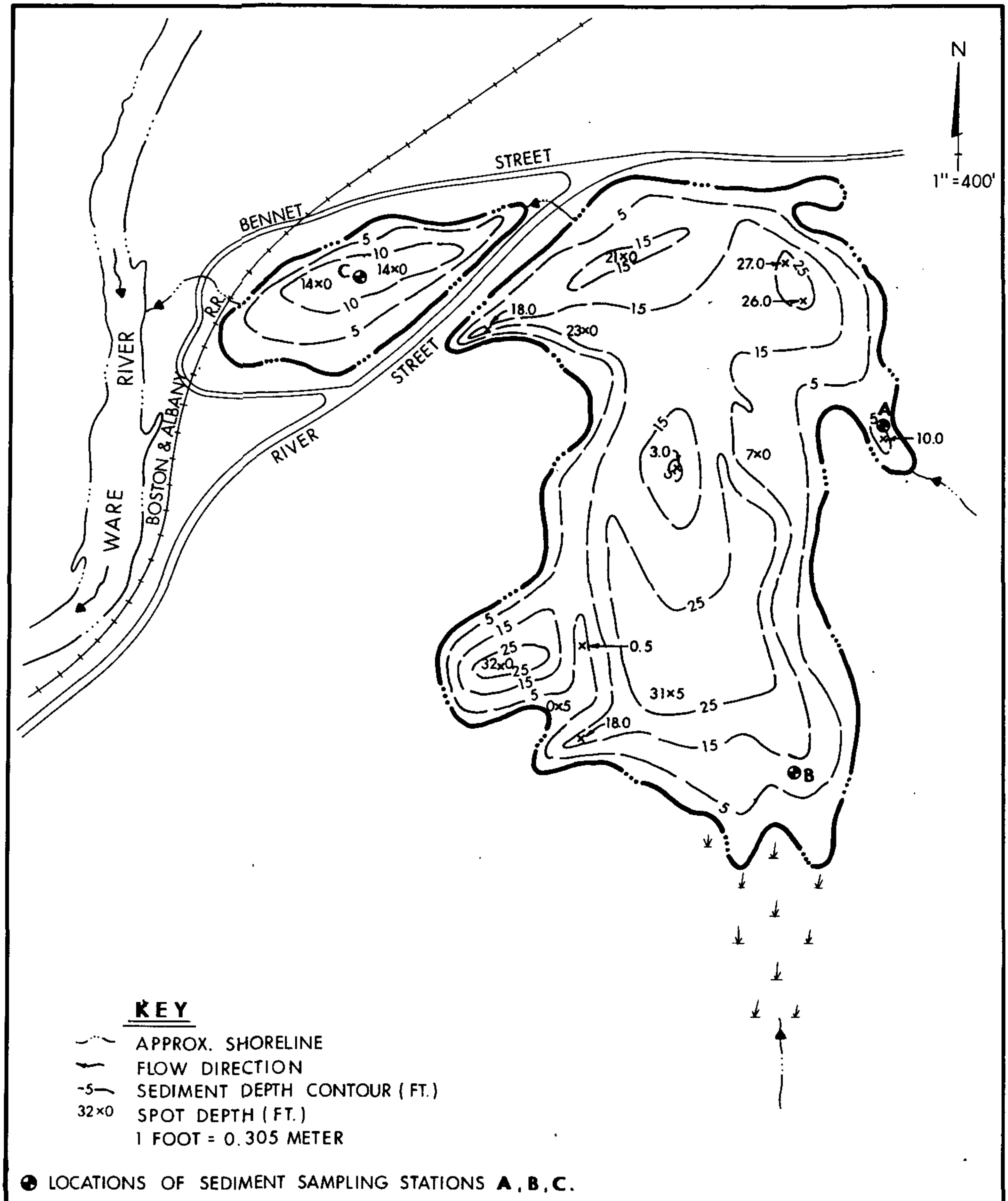
C. <u>Current Limnological and Sediment Data</u>

Tributaries to Forest Lake were sampled on September 25, 1980, November 20, 1980, February 20, 1981, March 26, 1981, April 27, 1981, June 5, 1981, July 14, 1981 and August 25, 1981; an in-lake station was sampled on the above dates except September 1980, February 1981 and April 1981; and seven (7) stormwater runoff grab samples were taken May 29, 1981. Laboratory analysis of collected samples was performed by Reitzel Associates, Boylston, Massachusetts, in accordance with Commonwealth/EPA-approved procedures.

Three (3) sediment samples were collected on April 27, 1981, at the sampling sites shown on FIGURE 5 for physical/chemical characterization based upon sediment depth and apparent hydraulic patterns. FIGURE 5 depicts apparent bottom sediment depths in Forest Lake by taking a grid system of "punchings" to hard bottom through winter ice cover in February 1981.

TABLE 5 provides temperature and dissolved oxygen values and TABLE 6 secchi disc readings and weather conditions for the in-lake station. TABLES 7, 8, 9,10 and 11 summarize pH, chloride, ammonia/nitrate-nitrogen, total phosphorus and additional parameters, respectively, for all evaluated sampling sites. Stormwater grab sampling results taken during the initial hour of a 1.2-inch rainfall event following a nearly two-week antecedent "dry" period are given in TABLE 12.

TABLE 13 gives sediment analysis results representing the top two feet of sediment. TABLE 14 compares average Forest Lake sediment characteristics to values obtained by MDWPC or the Central Massachusetts Regional Planning Commission for other pond and river resources in the area.



DEPTH OF SEDIMENT MAP

FOREST LAKE — PALMER, MASSACHUSETTS

FIGURE 5

TABLE 5
FOREST LAKE STUDY
DISSOLVED OXYGEN/TEMPERATURE
IN-LAKE STATION

	11-20-80		3-26-81		6-5-81		7-14-91		8-25-81	
	D.O. (mg/l)	Temp. (°C)	D.O. (mg/l)	Temp. (°C)	D.O. (mg/l)	Temp. (°C)	D.O. (mg/l)	Temp. (°C)	D.O. (mg/l)	Temp. (°C)
Surface	11.7	3	12.7	5	8.6	22	7.8	26.5	7.8	22.5
5' (1.5 m)	11.6	3	12.9	5	8.6	21	—	—	—	—
6' (1.8 m)	—	-	—	-	—	—	7.6	26.5	7.8	22.0
10' (3.0 m)	11.7	3.5	12.9	5.5	8.2	20	—	—	—	—
12' (3.7 m)	—	—	—	—	—	—	8.3	23.0	7.0	22.0
15' (4.6 m)	11.4	3.5	12.9	5	8.7	18.5	—	—	—	—
18' (5.5 m)	—	—	—	-	—	—	2.7	19.0	5.9	20.0
20' (6.1 m)	11.6	3.5	13.0	5	3.2	14	—	—	—	—
24' (7.3 m)	11.6	4	12.7	5	1.4	12.5	0.1	14.0	0	15.5

TABLE 6

FOREST LAKE STUDY
SECCHI DISC READINGS/WEATHER CONDITIONS

Sampling Date & Time	Secchi Disc Reading	Weather Conditions
11/20/80 (12:30 PM)	9 ft. (2.75 m)	air temp. = 5 °C, clear
3/26/81 (11:30 AM)	7.5 ft. (2.3 m)	air temp. = 10 °C, clear
4/27/81 (10:45 AM)	12 ft. (3.7 m)	air temp. = 19 °C, clear
6/5/81 (9:00 AM)	------	air temp. = 25 °C, clear
7/14/81 (10:00 AM)	8 ft. (2.4 m)	air temp. = 25 °C, clear and breezy
8/25/81 (9:15 AM)	8 ft. (2.4 m)	air temp. = 20 °C, partly cloudy w/ mild breeze

TABLE 7

FOREST LAKE STUDY
WATER QUALITY ANALYSES: pH

	4-27-81	6-5-81	7-14-81	8-25-81
Southerly inlet (Sta. 1)	6.6	6.5	6.2	6.0
Route 32 (Sta. 1A)	6.8	6.5	6.5	6.5
Above Fish Hatchery (Sta. 1B)	6.9	6.5	---	---
Easterly inlet (Sta. 2)	6.8	6.3	6.5	6.5
Outlet	7.0	6.4	6.0	6.0
In-Lake Station				
Surface	---	6.8	7.0	6.5
5' (1.5 m)	---	6.8	---	---
6' (1.8 m)	---	---	6.8	6.5
10' (3.0 m)	---	6.7	---	---
12' (3.7 m)	---	---	6.5	6.5
15' (4.6 m)	---	6.5	---	---
18' (5.5 m)	---	---	6.2	6.2
20' (6.1 m)	---	6.5	---	---
24' (7.3 m)	---	6.3	6.2	6.5

TABLE 8

FOREST LAKE STUDY
WATER QUALITY ANALYSES: CHLORIDE (MG/L)

	9-25-80	11-20-80	2-20-81	3-26-81	4-27-81	6-5-81	7-14-81	3-25-81
Inlet (Sta. 1)	21.6	25.9	24.4	24.1	14.8	15.9	16.3	25.3
Rt. 32 (Below Fish Hatchery)	----	----	----	23.6	27.2	19.8	19.2	----
Above Fish Hatchery	41.7	43.0	27.5	34.8	38.7	34.2	----	----
Inlet (Sta. 2)	27.3	22.3	10.5	12.3	25.1	20.5	20.9	24.2
Causeway	21.1	22.3	24.7	20.8	----	----	----	----
Outlet	21.6	22.5	27.7	20.6	23.1	20.0	21.7	20.1
In-Lake Station								
Surface	----	----	----	21.3	----	20.0	21.1	21.7

TABLE 9

FOREST LAKE STUDY
WATER QUALITY ANALYSES: AMMONIA-NITROGEN (MG/L)/NITRATE-NITROGEN (MG/L)

	9-25-80	11-20-80	2-20-81	3-26-81	4-27-81	6-5-81	7-14-81	8-25-81
Inlet (Sta. 1)	.08/.01	.04/.17	.14/.39	.09/.37	.05/.14	.07/.26	.11/.03	.04/ .01
Rt. 32 (Below Fish Hatchery)	---	---	---	---	---	---	---	---
Above Fish Hatchery	.03/.72	.01/.79	.07/.40	.04/.88	.04/.72	.06/.56	---	---
Inlet (Sta. 2)	.09/ .01	.01/.07	.03/.44	.02/.25	.07/.22	.09/.16	.03/.35	.04/ .01
Causeway	.07/.01	.03/.08	.01/.16	.04/.23	---	---	---	---
Outlet	.02/ .01	.01/.06	.01/.11	.02/.16	.04/.08	.08/.01	.08/.33	.04/ .01
In-Lake Station								
Surface	---	.01/.07	---	.03/.26	---	.04/.02	.12/ .01	.05/.12
5' (1.5 m)	---	.01/.07	---	.03/.27	---	.04/.01	---	---
6' (1.8 m)	---	---	---	---	---	---	.07/.01	.04/.12
10' (3.0 m)	---	.03/.07	---	.04/.27	---	.05/.03	---	---
12' (3.7 m)	---	---	---	---	---	---	.06/ .01	.05/ .01
15' (4.6 m)	---	.02/.07	---	.02/.27	---	.14/.06	---	---
18' (5.5 m)	---	---	---	---	---	---	.08/.02	.03/ .01
20' (6.1 m)	---	.03/.07	---	.02/.27	---	.26/.04	---	---

TABLE 10

FOREST LAKE STUDY
WATER QUALITY ANALYSES: TOTAL PHOSPHORUS (MG/L)

	9-25-80	11-20-80	2-20-81	3-26-81	4-27-81	6-5-81	7-14-81	8-25-81
Inlet (Sta. 1)	.01	.03	.08	.04	.01	.04	.08	.02
Rt. 32 (Below Fish Hatchery)	---	---	---	.08	.05	.05	.03	.03
Above Fish Hatchery	.01	.01	.13	.01	.01	.04	---	---
Inlet (Sta. 2)	.04	.03	.06	.01	.05	.08	.04	.02
Causeway	.01	.02	.02	.03	---	---	---	---
Outlet	.01	.06	.02	.02	.02	.02	.02	.01
In-Lake Station								
Surface	---	.04	---	.04	---	.05	.01	.02
5' (1.5 m)	---	.02	---	.07	---	.03	---	---
6' (1.8 m)	---	---	---	---	---	---	.02	.02
10' (3.0 m)	---	.03	---	.03	---	.02	---	---
12' (3.7 m)	---	---	---	---	---	---	.04	.02
15' (4.6 m)	---	.02	---	.02	---	.04	---	---
18' (5.5 m)	---	---	---	---	---	---	.02	.02
20' (6.1 m)	---	.02	---	.03	---	.04	---	---
24' (7.3 m)	---	.02	---	.04	---	.07	0.10	0.40

TABLE 11

FOREST LAKE STUDY
ADDITIONAL WATER QUALITY PARAMETERS

Water Quality Parameter	In-Lake Station (Surface) 3-26-81	In-Lake Station (Surface) 8-25-81	Southerly Inlet (Sta. 1) 4/27/81	Easterly Inlet (Sta. 2) 4/27/81	Upstream (Sta. 1A) from Hatchery 4/27/81	Rt. 32 (Below Fish Hatchery 4/27/81	Outlet 4-27-81
Hardness (mg/l as Ca Co_3)	22.7	35.8	29.6	25.6	35.5	31.1	27.6
Alkalinity (mg/l as Ca CO_3)	12.7	8.9	9.9	12.1	16.5	15.4	12.1
Conductivity (umho/cm)	121	131	83	114	169	112	106
Iron (mg/l)	0.3	2.3	0.1	0.5	0.1	0.3	0.2
Suspended solids (mg/l)	5	2	2	7	2	2	2
Surfactants (mg/l)	0.05	0.05	----	-----	-----	-----	----
Fecal coliform (per 100 ml)	0	17	1	0	0	4	2
Fecal strepto-coccus (per 100 ml)	0	0	2	0	2	0	0

TABLE 12

FOREST LAKE STUDY
STORMWATER ANALYSES*

Storm Sampling Location	WATER QUALITY PARAMETERS					
	Temp. (°C)	pH (Std. Units	Total Phosphorus (mg/l)	Ammonia Nitrogen (mg/l)	Nitrate Nitrogen (mg/l)	Chloride (mg/l)
1 paved ditch 300' easterly of causeway	19	5.5	0.29	0.21	0.63	12.1
2 paved ditch westerly of lake near Forest Lake Resort entrance	19	6.2	0.06	0.10	0.06	1.1
3 Rt. 32 storm inlet near fish hatchery	19	6.5	0.20	0.08	0.09	1.6
4 westerly 48" CMP culvert (Warren Street)	17	6.0	0.10	0.10	0.18	6.5
5 culvert Warren Street	16	6.0	0.24	0.04	0.07	22.0
6 12" CMP culvert at Burleigh Park	19	5.5	0.09	0.04	0.03	1.5
7 runoff along easterly side of Forest Lake beach (Bennett Street)	20	6.2	0.22	0.03	0.02	12.5

*obtained May 29, 1981 between 8:15 AM and 9:20 AM

TABLE 13

FORST LAKE STUDY
SEDIMENT CHARACTERISTICS

Parameter	Station A (Inlet 1)	Station B (Inlet 2)	Station C (minor basin)
Percent volatile solids	27.61	37.84	31.58
Odor assessment (t.o.n.)	1000	10,000	1,000
Percent moisture	81.46	93.01	92.10
Percent oil and grease	1.28	4.17	2.83
pH (std. units)	6.2	6.0	5.7
Ammonia-N (mg/kg)	126	127	122
Kjeldahl-N (mg/kg)	9,810	7,090	15,700
Total phosphorus (mg/kg)	188	170	218
Total sulfur (mg/kg)	7,000	7,000	7,000
BOD_5 (mg/kg)	3,020	9,400	5,890
COD (mg/kg)	278,000	551,000	473,000
Arsenic (mg/kg)	3.1	10.6	7.6
Barium (mg/kg)	130	110	100
Cadmium (mg/kg)	7	11	49
Chromium (mg/kg)	70	70	70
Copper (mg/kg)	32.7	68.7	118
Iron (mg/kg)	19,400	14,800	12,600
Lead (mg/kg)	90	100	170
Mercury (mg/kg)	0.14	0.45	0.47

TABLE 14

FOREST LAKE STUDY
COMPARATIVE SEDIMENT CONCENTRATIONS[1]

Parameter	Average Forest Lake	Cedar Pond Sturbridge	Lake Mattana Orange	Red Bridge Impoundment Chicopee River Wilbraham	Quinebaug[2] River Sturbridge
Percent volatile solids	32	37	--	--	2
Percent oil & grease	2.8	0.05	--	--	0.04
Total Kjeldahl-nitrogen	10,900	10,200	13,400	6,200	--
Ammonia-nitrogen	125	--	600	--	--
Total phosphorus	192	1,170	2,000	2,900	--
Percent chemical oxygen demand	43.4	--	--	--	1.6
Iron	15,600	25,700	28,000	22,000	--
Manganese	--	208	530	730	--
Copper	73	38	130	370	8.2
Lead	120	176	281	750	21
Mercury	0.35	0.22	--	--	--
Cadmium	22	--	4.4	320	0
Chromium	70	25	19	190	16
Arsenic	7.1	3.8	--	--	--
Zinc	--	216	300	750	25

(1) Values as mg/kg dry weight unless indicated as percent.
(2) Upstream of any known pollution source; sampled by CMRPC, 1978.

NOTE: Values for other lakes and ponds averages from MDWPC Surveys, 1975 - 1980.

D. Discussion of Water Quality Interrelationships

An assessment of the interfacing of bottom sediments with the overlying water; continuous surface and groundwater inflow; as well as intermittent stormwater runoff can assist in developing a brief summary evaluation of a complex chemistry. Parameters investigated as part of this Study and their possible influence on fish and wildlife resources, as well as pond uses are discussed as follows:

Transparency - Secchi disc readings of 8 feet taken during the two summer sampling periods are indicative of generally good water clarity for recreational use. The lowest reading of 7.5 feet in late March is likely related to high lake productivity from spring nutrient influx.

Temperature/dissolved oxygen - Forest Lake is a typical holomictic temperate pond in that isothermal conditions were recorded in spring and fall and mild stratification observed during summer.

Although temperatures below 18 feet (5.5 m) were below the Commonwealth's Class B cold-water fishery criteria of 68°F (20°C), concurrent low dissolved oxygen (DO) levels may limit fishery production. The Massachusetts warm-water fishery limit of 83°F (28.3°C) was not exceeded during the Study, although surface temperatures approached the limits in July. The cold-water fishery DO criteria of no-less-than 6.0 mg/l was violated below 15 feet depth throughout the summer, likely due in part to oxygen demand exerted by underlying sediments. Forest Lake summer temperatures generally are acceptable for growth of such historically-stocked warm-water species as crappie, bluegill, shiner, largemouth and small-mouth bass and yellow perch, while more-recently stocked rainbow trout require an estimated maximum weekly average of no greater than 19°C for suitable growth and prefer waters around 16°C. The recently-stocked brown trout likely are more tolerant of Forest Lake's summer temperatures.

pH - Inlet stream and in-lake pH values ranging from 6.2 to 7.0 occasionally fall below the 6.5 to 9.0 range recommended in EPA's Quality Criteria for Water to protect freshwater fish and their bottom-dwelling invertebrate food organisms. Slightly acidic conditions are most likely attributable to the reduced nature of the bottom sediments and tributary wetland influence on surface inflow.

Alkalinity/hardness/specific conductance - Forest Lake has a poor buffering capacity, similar to other lake resources in the region, as indicated by alkalinity values reported as mg/l $CaCO_3$. Recorded in-lake and tributary stream alkalinities fall below the EPA-recommended minimum of 20 mg/l $CaCo_3$ for freshwater aquatic life. Productive waterfowl habitats are reported to have alkalinities greater than 25 mg/l, while aquatic ecosystem diversity is generally correlated with higher alkalinities.

Reported total hardness values indicate a generally greater non-carbonate than carbonate hardness and a typical soft water. Non-carbonate hardness of up to 27 mg/l may be comprised of manganese, aluminum, strontium and zinc ions.

Specific conductance measurements are not remarkably high nor is there a marked seasonal variation in dissolved constituents.

Nitrogen - Resuspension of sediment material containing organic and inorganic nitrogen compounds, which may occur during recreational use (or improvement measures), from a reducing environment to the oxygenated water column may be important to the overall nitrogen budget.

Total nitrogen and total organic carbon are correlated in bottom sediments, as nitrogen in sediments is usually in the organic form. Decayed plant material has been shown to generally have a carbon: nitrogen ratio of about 10.1:1, with nitrogen levels generally decreasing with sediment depth. The total sediment nitrogen content is much greater than that in the overlying water in even highly eutrophic resources.

Mineralization (transformation to an inorganic form) of organic nitrogen in Forest Lake sediment to ammonium-nitrogen (NH_4^+ - N) and subsequent diffusion to the overlying water is indicated by summer water quality analyses. The fate of the ammonium ion may be oxidation by chemo-autotrophic bacteria to nitrite then to nitrate. The nitrate anion (NO_3 -) is fairly mobile and is a readily acceptable nutrient for aquatic plant growth. Further, microbial denitrification may occur, reducing nitrate to nitrous oxide (N_2O) or nitrogen gas which diffuses to the atmosphere under reduced conditions.

It has been shown that the ammonium content of interstitial water within a reduced sediment may accumulate to much higher concentrations than that of overlying water. Diffusion of this interstitial dissolved ammonium-nitrogen into the thin oxygenated surface layer of sediment, or across the sediment-water interface, has been shown to be an important source of both ammonium and nitrate-nitrogen in the overlying water column. Higher summer levels of ammonia than nitrate-nitrogen in Forest Lake water samples illustrate the apparent correlation between organic and ammonium-nitrogen in the sediments and subsequent ammonium-nitrogen values in the water column. Considerable amounts (some studies have shown up to 20 to 30 percent of the total budget) of sediment-bound nitrogen is released to pond or lake resources.

The pH values associated with Forest Lake reveal that the relatively non-toxic NH_4^+ fraction of ammonia normally predominates. However, based upon mid-late summer ammonia analyses of overlying water, correlated with pH and temperature measurements, the estimated concentration of the un-ionized NH_3 fraction, having variable toxicity to aquatic life, exceeds by up to five times the 0.02 mg/l limit recommended by EPA for freshwater aquatic life. This limiting value has been based upon 1/10 of the lowest reported lethal concentration of 0.2 mg/l NH_3 for rainbow trout fry - a concentration exceeded during summer in the deeper in-lake waters and in the inlet stream at the State Fish Hatchery at Route 32 in spring and early summer.

Concentrations of nitrate-nitrogen in Forest Lake should have no detrimental effect on freshwater aquatic life, as adverse effects on cold or warm-water fish have not been noted at levels below 90 mg/l NO_3-N. EPA has not established nitrate-nitrogen criteria for warm or cold-water fisheries due to relatively low concentrations in natural waters.

Greater than 98 percent of the total Kjeldahl-nitrogen (TKN) reported in Forest Lake sediments is comprised of organic-nitrogen constituents largely attributable to the abundance of aquatic macrophyte growth. Nitrogen concentration in the sediments compare well with similar pond resources in the area.

Comparison of inlet, in-lake and outlet nitrogen values would indicate a general decrease in non-organic nitrogen with flow through the lake during much of the year with little net change during summer, likely due in part to nitrification processes.

The following available nitrogen (inorganic) budget reveals an overall influx of nitrogen from the sediments during spring and summer periods averaging about 160 kg/yr. compared to about a 1,620 kg/yr. contribution for normal surface flow:

	surface influx	in-lake contribution	outflux
9/25/80	40 kg/yr.	-180 kg/yr.	220 kg/yr.
11/20/80	900	-150	750
2/20/81	4,470	-360	1,610
3/26/81	4,020	+160	4,180
4/27/81	1,180	+750	1,930
6/5/81	1,110	+20	1,130
7/14/81	720	+3,310	4,030
8/25/81	160	+240	400
Average Annual	1,620 kg/yr.	+160 kg/yr.	1,780 kg/yr.

Based upon stormwater sampling results, an estimated 310 kg/yr. inorganic nitrogen is contributed by storm drainage from adjacent shore areas.

Phosphorus - Total phosphorus concentrations in Forest Lake and tributary streams are generally indicative of relatively high phosphorus - availability. Comparison of inlet and outlet phosphorus values point to lake phorphorus retention during much of the year, except for late summer when near anoxic conditions in the deeper waters enhanced apparent phosphorus release from the sediments as dissolved inorganic P.

The following phosphorus budget reveals an overall influx of phosphorus from the sediments during much of the year averaging about 50 kg/yr. compared to about 210 kg/yr. contribution from normal surface flow:

	surface influx	in-lake contribution	outflux
9/25/80	90	+20	110
11/20/80	130	+510	640
2/20/81	630	-360	270
3/26/81	270	-40	230
4/27/81	160	+160	320
6/5/81	180	+70	250
7/14/81	170	+30	200
8/25/81	50	+30	80
Average Annual	210 kg/yr.	+50 kg/yr.	260 kg/yr.

Based upon stormwater sampling results, an estimated 180 kg/yr. of phosphorus is contributed by storm drainage from adjacent shore areas.

Sediment-bound phosphorus concentrations are nearly ten-fold less than those for similar area lake and pond resources. The oxidation-reduction potential controls the oxidation state of iron and thus affects the ability of sediments to retain or release inorganic phosphorus, while changes in pH of sediments can similarly affect phosphorus exchange. Relative sorption of phosphorus would occur at pH values measured in Forest Lake sediments. These sediments may be partially comprised of iron, calcium and/or aluminum phosphates which can serve as a buffering mechanism, regulating sediment-water phosphorus exchange. Organic phosphorus may constitute 10 to 70 percent of total P in lake sediments and that organic P is correlated with organic matter in some materials.

Sulfur - Substantial sulfur content in Forest Lake sediment is present chiefly as sulfide, although both sulfide and sulfate compounds likely occur, based upon pH values. Sulfate is readily reduced to sulfide in sediments containing decomposable organic matter. Precipitation of metallic ions and other trace metals as sulfides in sediments is important in regulating the solution concentration of both sulfide and the metallic ion, either of which may be toxic to aquatic life. However, an increase in dissolved oxygen concentration by sediment disturbance may result in sulfide oxidation, potentially mobilizing toxic substances. Sulfide generation is minimal under the pH conditions in Forest Lake, although significant odor potential exists under neutral-to-alkaline conditions.

Iron, manganese, zinc, copper, lead, mercury and cadmium ions readily form insoluble, relatively-stable sulfide compounds in reduced sediments containing sulfide. Iron, zinc, lead and nickel concentrations are more abundant in reduced sediment layers, indicating greater influence by sulfide precipitation.

EPA has recommended a limit of 0.002 mg/l of undisassociated H_2S for protection of aquatic life. As pH decreases to a value of 5, approximately 99 percent of sulfide present may occur as Forest Lake has not been analyzed; however, values obtained for sediments indicate possible long-term negative impacts upon less tolerant fish species from hydrogen sulfide generation by sediments under somewhat reduced conditions.

Iron - Iron concentrations in Forest Lake on tributary streams fall below the EPA-recommended limit of 1.0 mg/l for protection of freshwater aquatic life except for the late summer in-lake value of 2.3 mg/l. The toxicity and presence of various iron compounds is dependent upon alkalinity, pH, hardness and temperature.

Iron chemistry in sediment-water systems is important because of complexing with heavy metals, although iron itself is not generally considered a toxicant. Insoluble ferric (Fe^{+3}) iron in organically-derived sediments and soils has been shown to be present only near the sediment surface where total iron content is also highest. Soluble reduced ferrous (Fe^{+2}) iron tends to increase with sediment depth.

Forest Lake average sediment iron concentration is about 60 percent of that for similar pond resources surveyed by MDWPC.

In flooded soil and sediment systems comprised of significant organic material, ferrous sulfide is probably the predominant iron form, thus contributing to the black hue of reduced sediment material. Both oxidized and reduced forms of iron may complex with organic matter. Iron oxides absorb trace metals in an oxygenated environment and precipitate from solution, but under reducing conditions, iron may occur as soluble ions or compounds. Such chemical interrelationships are important in consideration of the environmental effects of pond rehabilitation alternatives involving oxygenation of reduced sediments.

Arsenic - Arsenic compounds are essentially insoluble in water; may be either organic or inorganic with trivalent inorganic forms generally more toxic to aquatic life and wildlife; and have been employed in a number of industrial uses, as well as herbicides.

Arsenic may be somewhat soluble, and, thus, available for micro-organism or vascular plant uptake under reduced conditions occurring in Forest Lake. Sorption processes evidently occur similar to those for phosphorus, with preferential sorption to amorphous iron and aluminum compounds. Arsenic levels in the overlying water of Forest Lake are not likely particularly adverse to fish and wildlife resources, but may be somewhat limiting to macrophyte and benthic invertebrate diversity.

Barium - Barium ions are readily precipitated from solution by absorption and sedimentation, although many barium salts are water soluble. Present in nature as highly insoluble salts, barium is utilized by the metallurgic, paint, glass and electronics industries. Previous studies have indicated that barium concentrations would have to exceed 50 mg/l before toxicity to aquatic life would be expected. Sufficient sulfate or carbonate commonly occurs in natural waters to precipitate the barium present as a virtually insoluble non-toxic compound. The barium concentration in Forest Lake sediment is not anticipated to adversely impact overlying water quality nor aquatic life.

Cadmium - Cadmium naturally occurs chiefly as a sulfide salt and is utilized in a variety of industrial processes. This metal is essentially immobilized in lake sediments under reducing conditions by complexing with sulfides, as would be the case with Forest Lake. Although fish and certain invertebrates are sensitive to low cadmium levels in water, particularly adverse concentrations in Forest Lake are unlikely.

Chromium - Rarely found in natural waters, chromium occurs in air, soil and most biological systems, and is utilized in various industrial operations. Available mainly as Cr^{+3} and Cr^{+4} - chromium, the hexavalent chromium is the form causing irritation and corrosion of animal tissue and that most likely to occur above a pH of 5 or greater. EPA has recommended a criteria of 0.10 mg/l chromium for protection of freshwater invertebrates and fish. Although fish appear to be relatively tolerant of chromium, some aquatic bottom-dwelling organisms have been shown to be quite sensitive depending upon particular species, chromium oxidation-state and pH.

Copper - Copper is utilized in the manufacture of electrical products, metal plating, paints and wood preservatives, as well as occurring naturally in minerals and soil. Values of 16 to 71 ppm have been found in various natural lake sediments compared to a value of 118 mg/kg in Forest Lake's minor basin.

The stable form of copper in natural conditions is the cupric (Cu^{++}) form, occurring as the absorbed form in soil complexes. Copper sulfide is a relatively stable compound in reducing environments, but yields cupric ions and sulfate when oxidized. Copper is one of the most mobile elements, although absorption on both organic and mineral colloidal matter may serve to reduce mobility. As conditions become more reducing, however, copper is much less mobile, as shown by formation of insoluble copper sulfide. Complexing of copper with organic materials may be an important control of copper availability in the overlying water column.

The toxicity of copper to aquatic life is dependent upon water alkalinity and pH, as the copper ion is complexed by toxic anions; at lower alkalinity, copper is generally more toxic to aquatic organisms. Copper concentrations less than 0.025 mg/l are not generally fatal for most common fish species, while salmonids are especially sensitive. Based upon relatively low alkalinity and pH of Forest Lake and copper concentrations in the upper sediment layer there may be present adverse influences on the more sensitive fish and bottom-dwelling species.

Lead - Lead concentrations in Forest Lake sediments generally compare with results for similar area water resources. Lead toxicity to aquatic life is influenced by pH, hardness, organic matter and presence of other metals. Lead in Forest

Lake is likely effectively immobilized by sulfide precipitation in the sediments under reduced conditions, particularly where clay or peat materials predominate. Concentrations of lead characteristically decrease with lake sediment depth.

Salmonids are generally most sensitive to lead in soft waters, with lead solubility likely approaching 0.5 mg/l in Forest Lake. Although such a concentration may not markedly cause adverse effects upon wildlife nor benthic life, chronic exposure under oxidized conditions may be detrimental to stocked trout species.

Mercury - Total mercury concentration in sediments is generally three orders of magnitude or greater than concentrations reported for natural waters, as mercury is readily complexed with organic carbon. Mercury concentrations in Forest Lake sediment indicate cultural influences. Although mercury concentrations in overlying water may not have direct marked adverse impacts upon aquatic life, microbial formation of toxic mono- and dimethyl mercury in the sediments may potentially cause bioaccumulation in fish tissue via benthic organism ingestion.

Oil and grease - Average oil and grease concentration in Forest Lake sediments exceeds that for nearby Cedar Pond by greater than 50 times. The persistence of unweathered oil within the sediments likely has a long-term chronic effect on the benthic community structure and loss of more sensitive species.

Bacterial contamination - Grab samples collected periodically and analyzed for fecal coliform and streptococcus bacteria indicate no apparent contamination by adjacent sewage disposal systems. A maximum fecal coliform count of 17 per 100 ml sample falls far below the Massachusetts Class B criteria of 200 per 100 ml for contact recreation.

Phytoplankton/chlorophyll -a - Phytoplankton counts and chlorophyll -a measurements given in TABLE 15 indicate relatively high primary productivity in Forest Lake during the spring overturn

TABLE 15

FOREST LAKE STUDY

ALGAL POPULATION/CHLORPHYLL-a
IN-LAKE STATION

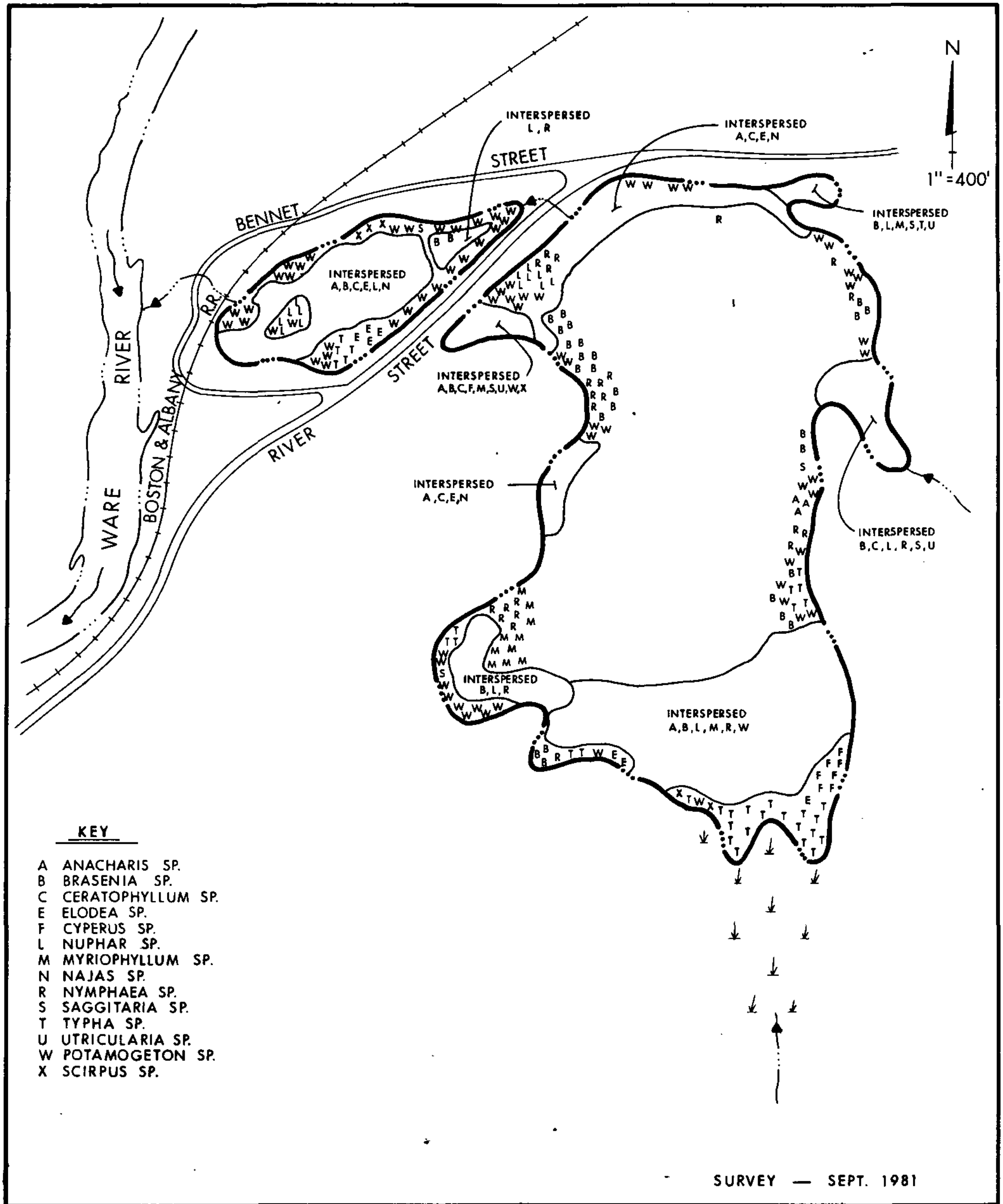
	Algal Population/100 ml - Major forms	Chlorophyll-a (mg/m^3)
11-20-80	86 - Asterionella, Cyclotella	2.4
3-26-81	1,000 - 95% Asterionella	3.67
6-5-81	242 - Asterionella	0.17
7-14-81	494 - Fragilaria	5.3
8-25-81	494 - Anabaena, Oscillatoria, Cyclotella	4.6

and moderate productivity throughout the summer. Relatively low productivity in the winter and late spring early summer is shown. The predominance of diatoms throughout much of the year giving way to nitrogen-fixing filamentous blue-green algae in the late summer is supportive of the assumption that nitrogen acts as the limiting nutrient.

Vascular plants (macrophytes) - Nuisance aquatic macrophyte surveys were conducted on June 29 and September 22, 1981. FIGURE 6 shows the extent of vascular plants observed, while the identified varieties are indicated as follows:

Major	Minor
Myriophyllum sp. (water milfoil)	*Anacharis* sp. (water weed)
Brasenia sp. (watershield)	*Elodea* sp. (water weed)
Potamogeton sp. (pondweed)	*Ceratophyllum* sp. (coontail)
Typha sp. (cattails)	*Najas* sp. (bushy pondweed)
Nymphaea sp. (white water lily)	*Vallisernia* sp. (celery)
Nuphar sp. (yellow water lily)	*Utricularia* sp. (bladderwort)
Cyperus sp. (sedge)	*Scirpus* sp. (bulrush)
	Saggitaria sp. (arrowhead)
	Juncus sp. (rush)
	Pithophora sp.
	Lemna minor (duckweed)
	Cephalanthus sp. (buttonbush)
	Hepaticae sp. (leafy liverwort)

Little change in the extent of surface coverage or species diversity occurred between June and September surveys. Although the density of emergent and floating macrophyte growth in some portions of Forest Lake increased, less than a 10 percent increase in area coverage was realized. *Pithophora* and *Lemna minor* was more notable in late summer in the quiescent cove and littoral areas.



NUISANCE MACROPHYTE MAP

FOREST LAKE — PALMER, MASSACHUSETTS

FIGURE 6

Stormwater runoff - Stormwater runoff grab samples were obtained at seven inlet locations during a 1.2-inch rainfall event occurring in a two-hour period on May 29, 1981, following a 13-day antecedent dry period. In addition to somewhat acidic rainfall, nitrogen and phosphorus influxes are slightly above ambient levels, particularly at the Bennett Street paved inlets.

Subsurface sewage disposal - The few year-round residences within the immediate shore area of Forest Lake presently can be expected to contribute a relatively small portion of the overall nutrient budget. Future shoreline development should consider the relatively low phosphorus-attenuation capacity of the sandy loams which predominate in this area. Little nitrogen attenuation in the soil prism between leaching facilities and the groundwater/lake interface can be expected.

Groundwater quality - In consideration of the extent of groundwater influence on the Forest Lake hydrologic budget, groundwater quality should be assessed. TABLE 16 gives limited well water analyses for the MDF&W Fish Hatchery. Groundwater is apparently slightly acidic and soft with no markedly high metals or nutrient concentrations. Well contamination by winter road salting activity on Route 32 has been reported by MDF&W.

Trophic condition - The overall trophic state of Forest Lake is mesotrophic approaching eutrophic based primarily on the EPA-NES delineation and the MDWPC Section 314 lake classification.

11. Biological Resources and Ecological Relationships

Information on fish stocking activity and water quality - fishery interrelationships have been addressed in the preceding section of this report. Forest Lake's stocked fishery is composed of species common to abundant throughout the region. Probable wildlife associated with Forest Lake or its tributary wetlands include beaver, muskrat and weasel, as well as various waterfowl, amphibians (turtle) and reptiles (frog).

TABLE 16

FOREST LAKE STUDY

GROUNDWATER QUALITY

Sampling Date	Location	Parameter - Value
1/10/73	4" (55 ft.) well	pH - 6.2 (std. units) Calcium - 7.7 (mg/l) Sodium - 13.1 (mg/l) Magnesium - 1.6 (mg/l) Manganese - 0.02 (mg/l) Iron - 0.12 (mg/l) Potassium - 1.8 (mg/l) Zinc - 0.0 (mg/l) Copper - 0.0 (mg/l) Total alkalinity - 20 (mg/l Ca CO_3) Hardness - 25 (mg/l Ca CO_3) Sulfate - 7 mg/l Chloride - 31 mg/l Dissolved oxygen - 13.9 mg/l Temperature - 35°F
	2" (70 ft.) well	pH - 6.2 (std. units) Calcium - 4.9 (mg/l) Sodium - 3.3 (mg/l) Magnesium - 1.1 (mg/l) Manganese - 0.00 (mg/l) Iron - 0.00 (mg/l) Potassium - 0.9 (mg/l) Zinc - 0.0 (mg/l) Copper - 0.0 (mg/l) Total alkalinity - 24 (mg/l Ca CO_3) Hardness - 18 (mg/l Ca CO_3) Sulfate - 2 (mg/l) Chloride - 11 (mg/l) Dissolved oxygen - 9.3 (mg/l) Temperature - 46°F Nitrate-nitrogen - 0.0 (mg/l)
4/1/65 - 3/31/66 (annual avg.)	unspecified well	pH - 6.3 (std. units) Specific conductance - 55.5 (umho/cm) Hardness - 22.0 (mg/l Ca CO_3) Dissolved oxygen - 8.2 (mg/l)

SOURCE: Massachusetts Division of Fisheries & Wildlife

SECTION III

FEASIBILITY STUDY: SCREENING OF ALTERNATIVES FOR AQUATIC VEGETATION CONTROL AND RECREATIONAL IMPROVEMENT

SECTION III

FEASIBILITY STUDY: SCREENING OF ALTERNATIVES FOR AQUATIC VEGETATION CONTROL AND RECREATIONAL IMPROVEMENT

1. General

Principal measures for pond or lake rehabilitation currently practiced are briefly described herein with a determination as to their general applicability or non-applicability to the characteristics of Forest Lake and its watershed. Those alternatives which appear to be technically feasible are further evaluated as to their specific engineering, economic, implementability and environmental concerns in SECTION IV of this report.

Alternative measures for rehabilitation include in-lake methods for unstratified resources (nutrient inactivation/precipitation, dilution/flushing, cutting/harvesting of aquatic macrophytes, bottom sealing, water level fluctuation/sediment exposure, herbicide application and dredging) and nutrient influx modification (through watershed management and inflow diversion or treatment).

2. Nutrient Inactivation/Precipitation

Inactivation or precipitation of phosphorus in a pond through additions of metallic ions (iron, calcium, aluminum) may change the form of phosphorus present to make it unavailable for aquatic plant growth or to prevent the release or recycling of potentially available nutrients within the pond. Inactivation is dependent upon nutrient sources, hydraulic and nutrient residence times and application methods available. The advantages of such an approach for shallow lakes and ponds have been relatively low cost, ease of application, and use of relatively low or non-toxic chemical or mineral additives. A covering of the pond sediment by flocculants may serve to reduce nutrient exchange from the upper sediment layer.

Disadvantages of phosphorus inactivation center on the long-term effectiveness of treatments and environmental effects. The formation of hydroxide precipitates by metallic ions may create problems with pH in relatively unbuffered waters (such as Forest Lake), possibly requiring addition of buffering agents to minimize pH changes. Bacterial solubilization of phosphates of aluminum, calcium and iron may occur, liberating phosphate from normally insoluble compounds under anaerobic conditions, and likely requiring additional treatments.

The more recent use of aluminum sulfate dosed to achieve pH reduction to 6 has provided long-term phosphate attenuation in the sediments and effective precipitation from the water column. However, existing slightly acidic conditions in Forest Lake and ample sulfur concentration in the sediments indicate substantial phosphate inactivation already occurs. In light of questionable benefits achieved upon implementation of a phosphorus inactivation program for Forest Lake, (due to the extent of shallow pond depth, low buffering capacity, anticipated lack of effectiveness in controlling primary productivity due to apparent nitrogen-limitation), this option has not been considered further.

3. Dilution/Flushing

The dilution or flushing of nutrient-rich waters from a lake or pond contributing to nuisance aquatic plant growth may be accomplished by (a) pumping water from the lake to permit increased inflow of nutrient-poor groundwater and (b) routing flows of nutrient-deficient surface waters into the resource.

Limited success may be expected where organically-rich bottom sediments continue to influence the nutrient concentration of overlying waters, thus, possibly requiring repeated dilutional or flushing operations. Although the costs associated with diluting Forest Lake with an increased proportion of groundwater inflow would be moderated by its nature as a spring-fed impoundment, the costs and environmental consequences of diverting surface waters from outside the natural watershed would be excessive.

Diversion of flows from any low-nutrient resource to Forest Lake is prohibited by the lack of suitable waters within the immediate area, while the configuration of the impoundment limits desirable sediment scouring capabilities. Forest Lake already possesses a reasonable natural flushing capacity, indicating the present bottom sediments to greatly influence nutrient concentrations in the overlying water.

In one prior dilution project for a sediment-laden Wisconsin lake, the removal of nutrient-rich water did not affect pond rehabilitation to the extent that either long-term decrease in nitrogen or establishment of sports fisheries were realized.

4. Cutting/Harvesting of Aquatic Macrophytes

The cutting and harvesting of aquatic macrophytes can be a feasible rehabilitation alternative (a) in ponds where nutrient input is relatively low and (b) in shallow ponds where a high biomass of macrophytes relative to total water volume is present, depending on overall nutrient budgets, nutrient content of bottom sediments, aquatic species and eutrophication degree. The 1977 DEQE survey of aquatic vegetation control practices in Massachusetts indicated limited success over the long-term. However, cutting, followed by harvesting of nuisance aquatic vegetation, may be a viable short-term solution to recreational use limitations.

Cutting efficiency of commercially-available equipment may be somewhat constrained by the difficulty of cutting the woody rooted portion (rhizomes) of water lily growth which has large nutrient storage potential and the shallowness of the southern portion of both the main basin and the entire minor basin.

The feasibility of utilizing cutting/harvesting as a short-term approach for alleviating nuisance aquatic weed problems in Forest Lake is further enhanced by the possibility of using equipment purchased or leased for macrophyte removal for other pond resources such as Crystal Lake and nearby Pattaquattic Pond - both Great Ponds, in the Town of Palmer. A cutting/harvesting approach for Forest Lake is further assessed in this Study due to relatively minor environmental concerns, availability of equipment and possible recurrent use for community pond or lake resources with similar conditions.

5. Pond Bottom Sealing

Pond bottom sealing by blanketing the sediment with PVC-coated fiberglass screen, or polyethylene sheeting has been shown to reduce the exchange of nutrients between organic sediments and overlying water or to eliminate the substrate for macrophyte growth.

Principal factors requiring consideration prior to implementation of bottom sealing or covering include (a) potential for physical/chemical disruption of bottom cover materials; (b) duration of positive benefits; and (c) environmental effects of sealing materials on benthic and other aquatic organisms.

The use of polyethylene sheeting is not a proven method of controlled nutrient release from the sediments nor minimizing macrophyte growth and is somewhat reliant upon ready level control capability. Necessary sheeting/anchoring with sand or gravel may eventually support succession of shallow-rooted macrophyte growth such as Najas flexilis. More expensive spun-bonded polypropylene will permit escape of gases from the sediment (and, thus, nutrient release) but does not require extensive anchoring. PVC-coated fiberglass screening has proven effective in controlling such macrophyte species as *Najas* and *Potamogeton* at up to ten-foot depth with no marked adverse changes in water column characteristics.

The temporary reduction of aquatic macrophyte growth effected by fiberglass screening approach may be extended by the periodic cleaning of accumulated sediment from the screens. Due to extreme shallowness in some portions of Forest Lake, possible establishment of aquatic macrophytes more suited to modified substrate and/or increased phytoplankton growth because of continued nutrient availability, implementation of such an approach in itself would not result in significant resource improvement.

6. Water Level Fluctuation

Fluctuation of a lake or pond's water level can be an effective, relatively low-cost means of temporarily controlling the extent of nuisance emergent and submergent macrophyte growth.

Several emergent macrophyte species identified in Forest Lake prefer a generally stable water level. Raising the normal water level of Forest Lake to control nuisance weed growth is not a feasible approach, due to the adaptability of other successive macrophytes and limitations imposed by abutting shoreline development. However, water level drawdown to expose aquatic macrophytes to freezing and allow sediment consolidation/dewatering has been proven an acceptable rehabilitation measure for some pond resources. Overwinter drawdown can serve to expose aquatic rooted plants to freezing and desiccation, as exhibited by the frost heaving of the rhizomes of water lily species. A decrease in the abundance of nuisance plant growth may be realized in areas which were still water-covered but frozen to the sediment interface.

The long-term effectiveness of water level drawdown is questionable, thus limiting the option's continuing success after the initial drawdown. Although the predominant emergent/floating macrophytes in Forest Lake - watershield and yellow and white water lily - are notably adversely impacted by overwinter drawdown, such shoreline-associated macrophytes as cattails and sedge may actually thrive, serving to reduce the Lake's effective surface area. Drawdown would have questionable effect on the majority of macrophyte species found in Forest Lake, thus likely influencing an overall insignificant reduction in macrophyte biomass.

Drawdown reportedly can significantly affect the density of sediments and the chemistry of the sediment-water interface. An increase in the oxidation state of the upper layer of sediments may retard the movement of phosphorus from the sediments to the overlying water, as may the physical stabilization of the upper, more flocculant layer of the bottom sediment. Physical changes, including continued consolidation for periods greater than a year following refill, may predominate, while nutrient characterization remains essentially the same for muck sediments. However, the possibility also exists that exposure of sediments may influence an increase in microbial degradation of organic materials, thus providing additional sources of inorganic nutrients for aquatic plant growth.

Drawdown has been previously recommended for shallow ponds or lakes where muck sediments are readily suspended in the overlying water by recreational use or wind/wave agitation and are significant contributors to the overall nutrient budget. The present motorboat horsepower limitation on Forest Lake should serve to reduce unconsolidated sediment disturbance.

Overwinter drawdown has merit for future consideration in this Study, in conjunction with other restorative methods, such as weed harvesting and/or dredging, due to minimal operational cost and susceptibility of relatively fine grained sediment to consolidation and proven success as a vegetative control measure but has little viability as a sole restoration approach.

7. <u>Aquatic Herbicide Application</u>

Treatment of pond resources by application of both organic and inorganic herbicides has been previously employed as short-term measure for the control of aquatic macrophyte growth. Although an easily implemented, relatively low cost short-term approach toward aquatic weed control, herbicide application does not in itself reduce the pond's nutrient availability and has a high potential for adverse or questionable impacts upon non-target species and the affected ecosystem as a whole.

Effective solely for the purpose of vegetative reduction, barring any increase in water depth or alteration of the sediment-water interface, herbicide application could entail the distribution of an estimated 2,250 to 4,500 pounds of 2, 4-D (granular) and/or up to 50 gallons of an Endothall derivative over the pond surface from a small boat.

In light of the possible reinvasion of resistant aquatic macrophytes or microscopic algal blooms responding to increased nutrient availability upon eradication of target species, subsequent reapplication, utilizing other suitable herbicide and/or algacides, may be required. It is anticipated that a single seasonal treatment with possible subsequent spot applications would be initially effective, with subsequent treatment frequency dependent upon success.

8. Dredging

Dredging of bottom sediments from a pond or lake is a successful long-term method of (a) enhancing recreational potential through the physical removal of aquatic macrophytes and a deepening of shallow waters and (b) the removal of nutrient-rich organic sediments. Limited information is available on particular application to small pond resources, since dredging has historically been primarily employed in maintaining navigable waterways. Hydraulic or mechanical dredging of organic sediments from Forest Lake, followed by dredge spoil disposal and/or utilization is a feasible rehabilitation alternative in light of the Lake's physical characteristics, sediment and water quality conditions and potential environmental or public use benefits. Evaluation of various dredge and disposal approaches, based upon potential beneficial and adverse impacts to the aquatic ecosystem, economic considerations and acceptability/implementability is further assessed in this Study.

9. Nutrient Influx Modification

Nutrient influx to a pond or lake (and thus extent of aquatic plant growth) may be controlled by management of land uses and activities within its watershed and/or the physical diversion of direct nutrient inputs. Review of nutrient budgets and limnologic characteristics of Forest Lake leads to the conclusion that such an approach may be beneficial as part of a long-range improvement program in conjunction with in-pond control method (s). However, both direct and indirect watershed nutrient contributions to the Lake, in themselves, are not of sufficient magnitude to induce the present extent of macrophyte growth or sport-fishery degradation, as indicated in the previous discussions of water quality and sediment conditions. Clearly, an in-pond approach toward rehabilitation for recreation/conservation purposes should be in the forefront.

10. Environmental Regulations and Planning Criteria Governing Improvement Measures

A. Waterways Regulations (Massachusetts G.L. Ch. 91)

Massachusetts G.L. Ch. 91 defines the authority of the Division of Waterways pertaining to waterways improvements including the construction, reconstruction, alteration and repair of culverts, conduits, pipes, walls and dams or other incidental work for waterways safety and improvement. Criteria for such work include the benefits to the general public and local interest as shown by municipal or other contributions. The regulations call for a public hearing to be conducted and the completion of a study and cost estimate prior to commencement of work. The SCS is authorized to share in the installation costs for erosion/sediment control measures, fish and wildlife work and recreation development.

B. Wetlands Protection Act (Massachusetts G.L. Ch. 131, S. 40)

The Commonwealth's Wetlands Protection Act and subsequent regulations administered by DEQE govern the alteration of wetland resources, including water level alteration, reduction of flood storage capacity and filling or dredging projects. Prior to any such work, the applicant must file a Notice of Intent with the appropriate regional office of DEQE and the local conservation commission whereupon a public hearing is held on the matter and an Order of Conditions issued by the local authority (or Superceding Order by DEQE upon proper appeal). Since the proponent for a Forest Lake improvement project may be the Division of Waterways, the wetlands approval procedure may be effectively streamlined.

C. Massachusetts Environmental Policy Act (MEPA) Regulations

Current regulations promulgated by the Commonwealth's Executive Office of Environmental Affairs (EOEA) for implementation of MEPA (Massachusetts General Laws Chapter 30, Section 63-62H) call for the submission and distribution of an Environmental Notification Form (ENF) for waterways projects involving:

a) construction, replacement or expansion of a solid fill structure with base area greater than 1,000 square feet in waters subject to G.L. Ch. 91 or Ch. 131, s. 40;

b) dredging or disposal of more than 10,000 cubic yards of materials; and,

c) filling, dredging, constructing, rip-rapping or otherwise directly altering more than 500 feet of waterway.

Preparation of an Environmental Impact Report (EIR) is automatically required for any project requiring alteration of ten or more acres of land subject to Ch. 131, s. 40.

D. <u>Massachusetts Eutrophication and Aquatic Vegetation Control Program (Ch. 722)</u>

The DEQE has implemented policy and guidelines for determining both short- and long-term improvement measures for lakes and ponds with public access through the Commonwealth's Eutrophication and Aquatic Vegetation Control Program (EAVCP). Based upon a two-step application and review procedure, whereby a municipality or agency outlines a proposed resource management plan, DEQE may finance a portion of program costs, in accordance with availability of appropriated funds. The provisions and planning criteria of the State program are particularly important to this Study, since the Division of Waterways and/or the Town of Palmer may be the proponent for the improvement of Forest Lake.

Alternative vegetation control measures previously described herein are recognized as short- and long-term techniques by DEQE. Criteria applicable to Forest Lake used for indicating possible rehabilitation approaches follow:

<u>Cutting/harvesting</u> of aquatic macrophytes is encouraged when:

a) shallow zones sustain dense macrophyte growth;

b) resources are smaller than 40 hectares (99 acres) in area; and,

c) where greater than half the surface area would require herbicide treatment and its potential adverse impacts upon private wells or non-target organisms.

<u>Aquatic herbicide/algaecide application</u> in Forest Lake is effectively restricted by the following:

a) More appropriate, economically feasible and practical methods of vegetation control are not available;

b) The herbicides or algaecides will not damage the stability and/or integrity of aquatic ecosystems;

c) The use of copper compounds for algal control will not occur in trout-bearing waters unless approved by the Massachusetts Division of Fisheries & Wildlife;

d) No treatment of lakes (or ponds) with herbicides and algacides, (other than copper compounds) will occur if shallow wells draw drinking water within 50 feet of the application area, unless written consent to treat is obtained from all affected well owners; and,

e) The use of herbicides may be carried out during the months of May through September, preferably during late spring and early summer.

Physical or chemical sealing of a large portion of Forest Lake would not normally be approved by DEQE in light of environmental impacts and various planning criteria.

Water level drawdown and exposure of sediments and aquatic macrophytes is encouraged when:

a) Drawdown will not have a significant negative impact on public or private wells;

b) Point and non-point sources do not contribute significant concentrations of nutrients to the Lake;

c) Dense growths of aquatic macrophytes are supported;

d) Drawdown will lower the water level or freezing level below the roots of target plant species;

e) Sediments contribute significant amounts of nutrients to the overall nutrient budget;

f) The technique is to be accompanied by excavating and removing nutrient rich sediments;

g) A significant negative impact due to drawdown will not occur on the biota or hydrologic cycle of wetlands adjacent to, downstream or upstream of the resource;

h) Macrophyte growth will not be stimulated by drawdown and sediment exposure;

i) Aquatic life present will not be adversely affected to an unacceptable degree; and,

j) Optimal timing of drawdown and subsequent refilling of the Lake is instituted.

The following limitations may deter an effective drawdown program at Forest Lake:

a) Significant groundwater seepage occurs into the Lake;

b) Drawdown may not lower the water or freezing level below the roots of target macrophyte species; and,

c) Macrophyte growth may be stimulated by drawdown and sediment exposure.

Dredging is encouraged when the following requirements are met:

a) Nutrient loading from the watershed is not sufficient to promote the development of present eutrophic conditions in the Lake (or pond) without the contribution of internal nutrient loading;

b) The dredging operation will improve the Lake (or pond) environment by:

    (1) removing significant quantities of sediments which are important sources of nutrients,

    (2) removing substrata promoting excessive plant growth;

c) Chapter 91 (Waterways Regulations) is complied with;

d) Significant release into the aquatic environment of toxic chemicals or elements from the sediment will not occur during dredging operations;

e) Appropriate measures (such as use of siltation curtains) will be taken to assure that turbidity levels in the resource do not exceed 30 JTU during the dredging operation;

f) The proposed portions of the resource to be dredged are relatively shallow (less than 15 feet);

g) Adequate steps will be taken to dispose of the dredged material in an environmentally safe manner;

h) The dredging operation does not cause significant negative impacts on downstream or adjacent wetland environments;

i) The anticipated benefits justify the costs;

j) When dredged sediments do not pose a health or environmental hazard because of toxic substances content, the beneficial use of the sediments is encouraged.

The applicability of such criteria to conditions on Forest Lake shall be discussed further in this Study.

In light of DEQE criteria, aquatic herbicide application and pond bottom sealing are not readily acceptable as rehabilitation measures for Forest Lake.

E. Section 314 (P.L. 92-500) Restoration of Public-Owned Freshwater Lakes

Section 314 and subsequent procedural guidance from EPA under the Clean Lakes Program set forth the criteria by which the Division of Waterways and the Town of Palmer may receive Federal financial assistance for implementation of a long-term restorative program. Upon application to EPA and their subsequent review of provided background data (diagnostic/feasibility study) and program outline, grants for up to fifty (50) percent of implementation costs may be authorized.

Section 314 funds are not generally granted for the harvesting of aquatic vegetation or chemical treatment unless such short-term improvement measures are a necessary preliminary part of more permanent rehabilitation measures.

F. Massachusetts Division of Water Pollution Control Regulations for Water Quality Certification for Dredging, Dredged Material Disposal and Filling

MDWPC adopted regulations in 1978 for compliance with G.L. Ch. 21 (Massachusetts Clean Water Act), governing dredgings disposal in the Commonwealth. The regulations set forth the scope of jurisdiction with regard to other Commonwealth and Federal requirements; information to be included in a permit application and appropriate sampling methods for providing such data; criteria for evaluating dredging program applications; and the process leading to approval (or denial) of an application following its submittal.

The general purpose of the MDWPC regulations is to establish the procedures for applicants proposing to dredge, dispose of dredged spoil and/or fill water resources of the Commonwealth to obtain a certification, in compliance with Section 401 of the Federal Water Pollution Control Act, that the project is consistent with other regulations, standards, plans and policies pertaining to water quality. Water quality certification by MDWPC is also required for such projects not subject to Section 401, but subject to either G.L. Ch. 131, S. 40 or G.L. Ch. 91. Proponents for projects categorically excluded under MEPA regulations must complete and submit a Standard Application Form; additionally, this form must be completed and distributed along with an ENF, should the project be categorically included under MEPA.

MDWPC's classification of dredged material by physical/chemical characteristics leads to a subsequent recommendation as to feasibility of dredge and disposal methods. Chemical characterization falls into three categories; the MDWPC ranges for the two generally-applicable classes for Forest Lake values obtained are as follows:

Constituent (ppm)	Category 1	Category 2	Forest Lake
Arsenic (As)	0-10	10-20	3.1 - 10.6
Cadmium (Cd)	0-5	5-10	7 - 49
Chromium (Cr)	0-100	100-300	70
Copper (Cu)	0-200	200-400	32.7 - 118
Lead (Pb)	0-100	100-200	90 - 70
Mercury (Hg)	0-0.5	0.5-1.5	0.14 - 0.47

Physical characterization of sediment to be dredged also falls into three types:

Item (percent)	Type A	Type B	Type C	Forest Lake
Percent silt & clay	0-60	60-90	90-100	80-90
Percent water	0-40	40-60	60-100	81-92
Percent volatile solids	0-5	5-10	10-100	28-38
Percent oil & grease	0-0.5	0.5-1.0	1.0-100	1.3-4.2

The classification of sediments to be dredged identifies the normally MDWPC-approvable methods of dredging and dredged material disposal. Forest Lake sediment falls into Categories 1 and 2 regarding evaluated chemical constituents except for cadmium which falls into Category 3. For physical characteristics, the sediment sampled is basically Type C, thus requiring the assumption of the more stringent conditions. Based upon general classification of Forest Lake sediment, either hydraulic or mechanical dredging methods are normally acceptable to MDWPC, while confined upland or in-pond disposal with effluent control and timing, as well as siting of operations to avoid fisheries impacts would appear to be the recommended approach.

MDWPC, upon review of a submitted Application Form, would subsequently certify that the proposed project, together with any conditions attached, ensures the maintenance of the Commonwealth's water quality standards and minimizes impact on the environment.

G. U.S. Army Corps of Engineers Section 404 Regulations

Project review and permit issuance for the dredging operations in Forest Lake by the District Engineer of the U.S. Army Corps of Engineers under the provisions of Section 404 of P.L. 92-500 is anticipated to be required since Forest Lake is an impoundment of the headwaters of a navigable water with out-flow normally 5 cfs or greater. Additionally, if any discharge from a dredged material containment site is applicable to sections of the Ware River or other waters meeting this criteria, the permit process would be required.

H. State and Federal Solid Waste Disposal and Water Supply Protection Regulations

The disposal of dredged material must be conducted in accordance with applicable regulations and guidelines of the Commonwealth and EPA for solid waste management and groundwater supply protection. Although the characteristics of Forest Lake sediments are not likely to constitute a hazardous waste, possible utilization or disposal of dredged material in sanitary landfill operations must comply with the Commonwealth's "Regulations for the Disposal of Solid Wastes by Sanitary Landfill" (Ch. 111, Section 150A). Handling and/or landfill disposal of dredged material should also follow current and proposed EPA guidelines to ensure effective environmental protection of water supplies in accordance with the Safe Drinking Water Act.

11. <u>Alternative Approaches for Rehabilitation of Forest Lake</u>

This Section has indicated the technically feasible options for in-pond control of aquatic macrophyte growth and overall recreational improvement to be:

a) Cutting/harvesting and/or mechanical raking of aquatic macrophytes; and,

b) Dredging to remove organic, nutrient-rich sediments and reduce nuisance macrophyte growth.

These alternatives are further evaluated in the following section of this report, in combination as a multi-phase approach toward Forest Lake's long-term improvement.

SECTION IV

FEASIBILITY STUDY: EVALUATION OF IN-LAKE REHABILITATION ALTERNATIVES

SECTION IV

FEASIBILITY STUDY: EVALUATION OF IN-LAKE REHABILITATION ALTERNATIVES

1. Technical Considerations

A. Cutting/harvesting of aquatic macrophytes

The cutting/harvesting of aquatic macrophyte growth in Forest Lake is a technically simple short-term rehabilitation approach for improving recreational use during summer months and enhancing aesthetic appeal. The use of a commercially-available apparatus, such as the CHUB ("Cutter Harvester Utility Boat," Aquamarine Corp., Waukesha, Wisconsin) would be a suitable means for removing submergent and emersed vegetation.

At an estimated cutting/harvesting rate of 1½ acre per eight-hour operating day (two-man operation), a single clearing of vegetation over a 15-acre portion of the main basin may take up to 10 days.

The harvested weeds would be carried to shore for removal to a disposal area, which would most probably be the Palmer sanitary landfill. In addition to the two men required for operation of the cutter/harvester, personnel would be required for removal and disposal of accumulated macrophytes.

Alternative use of a "mechanical rake" apparatus would allow for macrophyte (as well as some roots and sediment) removal for up to 12 feet below the surface, as opposed to the five-foot depth limitation imposed by the CHUB harvester. Up to 40 days would be required to treat a 30-acre portion of Forest Lake.

B. Hydraulic and mechanical dredging methods

Consideration of a number of factors (including access, shoreline configuration, location and area of lake to be dredged, existing water depth and water volume, final water depths, location and distance to disposal sites, volume and type of sediment to be dredged, hydrologic/hydraulic concerns, feasibility of drawdown and refill, availability of equipment and its maneuverability) is essential for determining a most technically feasible dredging approach. Mechanical dredging in conjunction with impoundment drawdown and hydraulic dredging are considered herein.

A large proportion of dilution water (with subsequent possible effluent pollution concerns, increasing energy consumption requirements and greater disposal area requirements) is required when sediment removal by hydraulic dredging is employed, while mechanical methods entail sediment removal at near-bottom density. However, cutterhead pipeline dredges are commercially available and widely used for in-pond application and would appear to be the most effective hydraulic dredging apparatus for use at Forest Lake.

Cutterhead pipeline dredge

The cutterhead pipeline dredge employs a rotating cutter on the end of a dredge ladder, which physically excavates the bottom material, mixes it with dilution water and pumps the mixture hydraulically through floating and shore discharge lines to disposal sites. Booster pumps may be required for greater haul distances. Equipped with the proper cutterhead, this dredge can excavate a wide range of bottom materials. In a recent comparison of hydraulic dredges by the U.S. Army Engineer Waterways Experiment Station, the National Car Rental System, Inc., MUD CAT Model MC-915 was determined a particularly suitable apparatus. The 38-by-8 foot craft is propelled by a winch and cable system anchoring it to shore and requires a two-man crew for operation. With eight-inch suction and discharge pipe and 2,000 gpm flow rate, approximately 65 cubic yards/hour may be excavated within a depth range of 2.25 and 15 feet, depending upon particular in-pond conditions.

Comparison of Forest Lake storage capacity and hydraulic requirements of the MUD CAT dredge indicates that suitable water volume is available for hydraulic dredging operations.

The cutterhead hydraulic dredge would be capable of dredging Forest Lake to apparent firm bottom for up to 70 percent of its total surface area. However, shoreline configuration and water depth would limit the efficiency of dredge operation in the shallow, southern-most area of the main basin and the entire minor basin.

The nature of the dredged slurry from hydraulic operations would necessitate the development of either a diked in-pond or upland disposal area. The MDWPC requires that effluent control measures be implemented to contain dredged sediment of the type present. The assessment of preliminary engineering aspects includes consideration of such factors as hydraulic transport system requirements; volumetric, siting and construction criteria for the disposal area; and drainage/effluent control aspects.

In-lake diked disposal area

The construction of an in-pond dike to contain hydraulically-dredged material may serve to reduce operational problems associated with overland pipeline transport distances to suitable upland disposal sites. Factors which must be examined for design and construction of retaining dikes are dike geometry, foundation conditions, dike materials, stability (shear strength), seepage, settlement, erosion and construction methods.

Assuming recommendations of the U.S. Army Corps of Engineers, a minimum crown width of 6 to 8 feet, a freeboard of 2 feet, and side slopes not steeper than 1.5 : 1 for dikes constructed of semi-compacted dredged material with high silt, clay and organic content should be allowed. The construction of a dike in Forest Lake's main basin would most feasibly be undertaken in the southwesterly cove area near the Forest Lake Resort. This portion of the impoundment has shallow water and a shallow sediment depth barrier with sediment apparently underlain by coarser sandy-gravel firm bottom and has relatively few adjacent residences.

Placement of a dike structure could be accomplished by mechanically dredging the sediment material by means of dragline and earth-moving equipment.

In order to minimize the area required for dredged material containment, a lesser flow rate would be required to maintain effluent quality. An estimated 59,000 square feet would theoretically be sufficient for retaining 100 percent solids in the slurry at an influent flow rate of 1000 gpm (approximately 1/2 the capacity of the MUD CAT), based upon the following equation developed for preliminary design of dredged material disposal sites:

$$A = (785.5) \times (F) \times (Q) \div D^2$$

where: A = settling basin surface area (ft^2)

F = over-design factor = 1.2

Q = influent flow rate (gpm) = 1000

D = diameter of smallest particle to be removed (micrometers) = 3, for Forest Lake sediment

$$A = (785.5) \times (1.2) \times (1000) \div 9 = 105{,}000 \text{ ft}^2$$

The formation of an assumed maximum 10-foot high dike from excavated bottom material and/or more stable borrow material necessary to enclose such an area would only have an approximate 39,000 cubic yard storage capacity. Thus, a larger containment facility would be required or periodic removal of dredged material (upon draining and consolidation) from the containment area would be necessary for continued use.

In-lake diked disposal of hydraulically-dredged material in Forest Lake is not considered feasible due to the extent of disposal area required, costs of materials handling and time required for effective dredged material dewatering and consolidation.

Upland disposal of hydraulically-dredged material

The disposal of hydraulically dredged sediments via pipeline transport to a confined upland disposal area in the vicinity of Forest Lake has been evaluated. Factors to be considered in the design of an effective hydraulic transport pumping system include the density and quantity of dredged materials, as well as location of a disposal facility.

Pipeline transport of bottom materials excavated by cutterhead dredge apparatus to nearby disposal sites is severely limited by the scarcity of public or commercial/industrial open space parcels with suitable land area; excessive topographic constraints (elevation rise, wetland resources); residential development; lack of temporary access; and relatively long haul distances.

Mechanical dredging during drawdown

Mechanical dredging via a track-mounted dragline apparatus could be effectively utilized, following impoundment drawdown, to excavate Forest Lake sediments to desired depths. In consideration of engineering criteria, mechanical dredging generally requires less power consumption, smaller disposal areas and is more adaptable to long distance transport than hydraulic means.

A large conventional track-mounted dragline can cast its bucket up to 100 to 125 feet, while smaller machines reach only 50 to 75 feet. This rather limited reach and the requirement of stable, level ground on which to operate the equipment would necessitate sediment excavation to hard bottom outward from the accessible shoreline areas, so that the dredge and hauling equipment may progress further into the Lake to reach sediment deposits greater than 125 feet from shore.

A dragline apparatus referred to as the Sauerman crescent bucket operates on the same principle as the conventional dragline, except that it has a much greater reach (approaching 1000 feet when utilizing special hoist equipment). The bottomless bucket is hauled across the Lake by two cables and a drum hoist (or crane) which is mounted on the near shore. The load cable is attached to the front of the bucket and transmits the power for pulling the bucket across the pond bottom. The second cable, known as the track cable, acts as the carrier for returning the bucket toward the far shore. This cable is aerial and is attached to the hoist on the near shore and anchored on the far shore.

Varying sediment depths, shoreline configuration and access limitations would necessitate a combination of both described dragline methods for mechanically dredged Forest Lake. The Sauerman-bucket apparatus may be utilized for removing sediment to a point where conventional dragline or other suitable earth-moving equipment may load it on trucks for disposal or productive use at other sites. Mechanical dredging during the winter months following impoundment drawdown would involve scheduling of dredging operations so as to allow efficient drainage and consolidation of sediment material prior to removal.

The most apparently suitable dredgings disposal site in the vicinity of Forest Lake is the approximate 12-acre gravel borrow site situated adjacent to the State Fish Hatchery property along the southerly side of Route 32. Closed-out portions of this gravel-removal operation within the Forest Lake watershed may serve to provide effective dewatering disposal and/or storage-prior-to-reuse of dredged material. An average four-mile round trip would be required to haul material to the site.

Productive utilization of dredged material

The productive use of dredged material from Forest Lake excavated by mechanical dredge methods followed by dewatering/consolidation measures is worthy of careful consideration due to potential economic return and resource conservation objectives. Review of sediment characteristics, general conditions in the planning area and engineering criteria for various use concepts has indicated utilization in solid waste management, agricultural and erosion control applications to warrant evaluation.

Vegetative growth assessment

The feasibility of establishing grass growth and other stabilizing types of vegetation on dredged material from Forest Lake, whether as landfill cover material, agricultural area or other land improvement concept is promising, based upon review of reports on vegetative establishment for previous dredging projects.

Previous information developed to date concerning the ability of vegetation to stabilize dredged material and improve the quality of effluents or drainage from disposal sites has been scarce. However, common freshwater vegetation has varying capabilities in these regards, based upon recent research efforts and field investigations.

Nitrogen and phosphorus uptake by plants adapted to wet soils or aquatic conditions can be significant as indicated by their percentage of total plant biomass for some species. Nitrogen yields for cattails, waterwillow and duckweed range to over 13,000, 2,500 and 6,000 mg/kg, respectively. Although plant uptake of heavy metals, such as chromium or copper, is not particularly significant compared to values for nitrogen and phosphorus, iron contents of plant material approach those for phosphorus.

The establishment of appropriate vegetation at the periphery of a mechanical-dredge site may effectively serve to minimize contaminant concentrations in effluents or drainage waters, while plant propagation (and harvesting) may improve dredged material dewatering and consolidation.

Solid waste management

The utilization of dewatered dredged material as a final cover material for the Town of Palmer's present and prior sanitary landfill operations has been assessed due to the potential to support vegetation and subsequently control surface water infiltration, minimize blowing litter and minimize oxygen penetration. In general, the use of dried dredged material as a cover is operationally feasible, since it can be easily hauled, spread and compacted by conventional earth-moving equipment.

The present Town of Palmer sanitary landfill operation is located southwesterly of the Palmer Municipal Airport runway off Emery Street. The landfill is situated a short distance from the Ware River only about one-half mile north of Forest Lake. Since suitable final cover material must be hauled to the site to meet requirements for cover, as set forth in operational plans and specifications, haul of dewatered dredgings to the site may be feasible.

<u>Agricultural use of dredged material</u>

The addition of dredged material to a marginal soil can alter its physical and chemical characteristics, so that water and nutrients may become more available for the growth of plants. Additionally, raising the elevation of the present soil surface with dredgings may improve surface drainage, reduce flooding and reduce water table elevations, subject to environmental compatibility. The agricultural use of dredged/sediments depends upon such factors as physical/chemical characteristics, potential for weed propagation, site preparation requirements and particular farming operations.

The mixing of fine-textured dredged material, relatively high in clay and silt proportions, with a coarse-grained soil (high in sand content) to the proportions of a suitable loam would improve the physical/chemical characteristics for supporting a crop growth. Upon comparison of Forest Lake sediment textural characteristics with limits recommended by USDA, the sediment is basically a silty-clay/loam.

Sandy loams are generally preferable for vegetable root crops (such as carrots, beets and potatoes), while loam to silt-loam soils are more suited to row crops, orchards and small grains.

Upper sediments from Forest Lake are suitable for establishment of most agricultural crops, relative to estimated potential for adequate water storage capacity.

Non-food crops, which may include lawn sod and related horticultural products, and food crops, such as small grains, row crops, pasture-land and orchards are generally practical means of utilizing dredged material. The propagation of crops in dredged sediments containing heavy metals, which may exhibit toxicity upon accumulation in plant tissue, requires the prior assessment of anticipated toxicity tolerance limits. Review of metals analyses data indicates that the two (2) metals present in Forest Lake sediment in a concentration which may be deleterious to plant propagation are chromium and cadmium. Generally, minimal uptake of heavy metals in grain crops makes them desirable for production, where accumulation in the leaves does not preclude them from forage or silage use. Such an approach for Forest Lake sediment may be viable, pending plant bioaccumulation analyses.

An estimated 7 to 12 metric tons of lime per hectare would be required to bring sampled Forest Lake sediment to a pH of 6.5, which is most conducive to growth for most crops. However, lime addition may not be prerequisite to suitable grass growth. Recommended fertilizer requirements would indicate both the nitrogen and phosphorus concentrations in Forest Lake sediment to be more than adequate to support crop propagation, although potassium and other micro-nutrient concentrations are not known.

Agricultural land use in the project area is such that marketing of dewatered dredged material for application to marginal soils for improved plant growth may be possible. The large areas of excessively drained and organically-deficient Merrimac and Hinckley soils in the area may be effectively enhanced by application of dredged material.

Dewatered dredged material applied as a surface cover over areas too rocky, gravelly or other wise unsuitable for cultivation should approach depths of 1 to 3 feet to allow good drainage and adequate rooting. Flat or nearly level (less than 10 percent slope) fields are the most feasible application sites.

Use of dredged material for erosion control

Dewatered dredged material may be used effectively for the control of erosion and subsequent stream sedimentation through establishment of suitable stabilizing vegetation, as indicated by the previous discussions on landfill cover and agricultural uses.

Sites upon which dredged material placement and grading with subsequent planting may provide erosion control and productive sediment usage, include sand/gravel borrow areas approaching non-productivity and construction sites undergoing soil removal. Dredged material marketing for land reclamation purposes may be a feasible means of off-setting project expenditures.

Publicly-owned areas possibly benefitting from dredged material application may include areas requiring soil stabilization along roadway and highway easements which may require slope stabilization or use of low-strength fill material.

The SCS has recommended that a minimum depth of four inches of topsoil for supporting grass growth be placed over completed gravel borrow sites. Lime addition and/or mixing with coarser, inorganic soils may be desirable to establish vegetative cover and provide workability of the material. Irrigation may be necessary to prevent excessive drying and cracking of the dredged material layer during germination and initial growth. TABLE 17 presents a listing of grasses, herbs, shrubs and trees commonly used for revegetating disturbed areas potentially adaptable to growth on Forest Lake sediment, based upon review of growth suitability criteria of SCS and the U.S. Army Corps of Engineers. Depth of dredge fill would be an additional criterion for ultimate species selection.

2. Economic Evaluation

The economic evaluation of rehabilitation alternatives presented herein is based upon information provided by equipment suppliers, service contractors, evaluation reports of the EPA and the U.S. Army Corps of Engineers and current construction cost estimating guides. An interest rate of 8 percent over a 10-year planning period has been assumed in development of present worth and equivalent annual costs.

A. Cutting/harvesting of nuisance macrophytes

Operation of the Aquamarine Corp. CHUB apparatus on a contract basis has been assumed. Cost comparison between a purchase option and a per-hour contract services option has indicated the latter approach to be the most economical,

TABLE 17

FOREST LAKE STUDY

VEGETATION SUITABLE FOR UPLAND DREDGINGS STABILIZATION

Grasses

Broomsedge
Green bristle grass
Large crabgrass
Oats
Orchard grass
Quackgrass
Sand dropseed
Smooth crabgrass
Wheat
Yellow bristlegrass

Herbs

Alsike clover
Black medic
Common chickweed
Common filaree
Common lambsquarters
Common ragweed
Giant ragweed
Hairy vetch
Horse nettle
Horseweed
Japanese clover
Korean clover
Lespedeza
Mapleleaf goosefoot
Partridge pea
Prostrate knotweed
Purple nutsedge
Spotted burclover
Tansy mustard
Tumbleweed
Virginia pepperweed
Western ragweed
Wild bean
Wild sensitive pea
Wild strawberry
Yellow sweet clover

Shrubs/Small Trees

American elderberry
American hornbean
American plum
Bayberry
Beach plum
Canadian serviceberry
Eastern hophorn bean
Flowering dogwood
Gallberry
Russian olive
Thorny eleagnus

SOURCE: Annotated Tables of Vegetation Growing on Dredged Material Throughout the United States, U.S. Army Engineer Waterways Experiment Station, 1978 particularly in light of operation, maintenance and storage needs. Based upon current prices, operational requirements and an expected cutting/harvesting frequency of once per year for a 14-acre portion of the main basin the following is estimated:

CHUB Services	\$ 6,500 / yr.
Material disposal	\$ 400 / yr.
Present worth of cutting/harvesting	\$46,300
Equivalent annual cost	\$ 6,900
Equivalent annual cost per acre treated	\$ 500

B. Use of mechanical rake

Operation of a mechanical rake apparatus on a contract basis has been assumed. Based upon treatment of a 24-acre portion (up to 12 feet deep) of the main basin and the entire minor basin and an expected operational frequency of three times each within the ten-year design period, the following cost summary is given:

Mechanical rake services (initial)	\$ 34,500 / yr.
Subsequent treatments	\$ 11,400 / yr.
Present worth of mechanical raking	\$111,000
Equivalent annual cost	\$ 16,500
Equivalent annual cost per acre treated	\$ 550

C. Combined mechanical rake/cutting-harvesting

Use of a mechanical rake to initially treat 24 acres of the main basin and the entire minor basin followed by CHUB macrophyte harvesting annually for the same 30 acres in the third through tenth years of the assumed planning period yields the following costs:

Mechanical rake treatment	\$34,500
CHUB services	\$ 4,800 / yr.
Present worth cost	\$66,700
Equivalent annual cost	\$ 9,940
Equivalent annual cost per acre treated	\$ 350

D. <u>Mechanical dredging with permanent impoundment drawdown structure and upland disposal</u>

Costs associated with removing 350,000 cy of sediment from Forest Lake, hauling and placement/grading or material at the Route 32 gravel-borrow area and construction of a permanent drawdown conduit at the minor basin are summarized as follows:

Dredging operations	$ 905,000
Material hauling	$ 925,000
Site preparation/grading	$ 255,000
Groundwater protection	$ 50,000
Drawdown conduit	$ 10,000
Present worth cost	$2,145,000
Equivalent annual cost	$ 319,700
Equivalent annual cost per acre	$ 7,100

Costs presented do not reflect any application of dredged material for productive use concepts resulting in a potential cost savings. Equivalent annual cost per acre assumes entire lake to benefit from dredging.

3. <u>Environmental Concerns</u>

A. <u>Cutting/harvesting and/or mechanical raking of aquatic macrophytes</u>

The cutting and harvesting of aquatic macrophytes can result in several short-term impacts on the aquatic environment. Agitation of the sediment-water interface during cutting operations can result in the release of nutrients to and increased turbidity of overlying water. Such nutrient release in conjunction with any release from the cut vegetation itself may be utilized by other plant growth, potentially resulting in microscopic algal blooms. Furthermore, the efficiency of cutting/harvesting operations permits some vegetation to remain, possibly contributing to future growth. In particular, the rhizomes of waterlilies are not particularly susceptible to cutting, but are normally removable through mechanical raking.

The improper disposal of harvested macrophytes, could result in nuisance growth in an adjacent lake or pond and generation of odors from microbial degradation of the plant material.

B. Water level drawdown during mechanical dredging

Impacts upon the aquatic environment from drawdown of the lake level to expose macrophytes and sediments for dredging may be somewhat questionable, upon review of information available to date.

Large increases in ammonia-nitrogen during repeated cycles of freezing/thawing may be attributed to microbial degradation of cellular organic materials. Exposed organic sediments may release several times more CO_2 than submerged organic sediments. Chemical interrelationships particular to Forest Lake, such as the potential for iron complexing with phosphorus, determines the extent to which chemical changes will occur.

Sediment consolidation may create difficulty for benthic organisms to reestablish themselves upon reflooding in non-dredged areas, while overwinter drawdown will subject some fish and benthic organisms to freezing. Drawdown of Forest Lake would result in temporary increases in flow and possible sediment loading downstream to Ware River; however, effective control of drawdown would minimize any adverse impacts.

Level drawdown may influence a lowering in the water table of the impoundment area, thus potentially affecting adjacent shallow wells. Determination of well depths for possibly affected residences prior to impoundment drawdown would be prerequisite to implementation.

C. Mechanical dredging and upland disposal

The environmental impacts of dredging sediment from Forest Lake are primarily associated with 1) the actual dredging operation and 2) disposal and/or use of dredged material, assessed from both short- and long-term viewpoints.

Mechanical dredging would entail the physical disruption of the bottom environment with decimation of the existing benthic community likely. Although many species of sediment dwellers are capable of moving vertically through the sediment, proposed dredging to apparent hard bottom for a substantial area essentially precludes reestablishment of the same benthic community following dredging operations.

The oxidation of reduced sediment materials during dredging will likely result in an increase in pH of the sediment and a decrease in water pH. Such an increase in sediment pH, coupled with physical disruption, could entail release of contaminants.

The U.S. Army Corps of Engineers has reported that release of sediment-associated heavy metals and subsequent aquatic organism uptake is not generally significant for dredging projects. However, the actual potential for heavy metals release from disturbed sediment material is not clearly understood. The concept that the oxidation of sulfide to sulfate will release complexed metals opposes the theory that metals can be coprecipitated with iron and manganese hydrous oxides. Considering the relative insolubility of copper sulfides, the scavenging effects of iron toward heavy metals, and ready precipitation of chromium and mercury under oxidized conditions, significant toxic metals release to the environment would not be anticipated.

Disturbance of oil and grease residues in the sediment is not likely to significantly impact aquatic life in drainage-receiving waters. Such residues are tightly bound to sediment particles and possibly less than 0.01 percent of that contained in the sediments may be released. Pesticide residues characteristically comprise part of this fraction.

Reduction in alkalinity (32 percent average) and increase in pH (0.5 unit average) in effluents from freshwater dredged material disposal sites has been generally reported. However, an increase in alkalinity may occur from the possible microbial degradation of vegetative material releasing CO_2, which may, in turn, induce dissolution of metallic carbonates present under increasingly acidic conditions.

Sulfide oxidation could result in a transfer of metals from low-solubility sulfide compounds to sulfate compounds with increased solubility. Although such oxidation is relatively slow, long detention would enhance this process.

Soluble ammonia-nitrogen and organic nitrogen removals during dredgings containment (with subsequent increase in nitrate-nitrogen concentration) may be of concern, since average effluent or drainage concentrations of potentially toxic ammonia-nitrogen from freshwater dredge disposal sites approximate 9 mg/l. Subsurface drainage from a containment area for Forest Lake dredged sediments may consist of higher total nitrogen values with questionable impact upon groundwater quality without groundwater protection.

Soluble phosphorus (mainly orthophosphate) levels anticipated in drainage from the disposal area may enhance algal productivity in any immediate quiescent receiving waters.

Water quality impacts from oil and grease in disposal area drainage is not anticipated. Approximately 99 percent of total oil and grease may be retained in confined disposal sites, due to association with the dredged material.

Leachate migration to groundwaters underlying the disposal site may be of concern without provision for groundwater collection. Recent investigations into the migration of constituents from upland dredgings disposal sites to the groundwater regime have been reviewed. Soil absorption, complexing and precipitation/dissolution processes tend to minimize the threat of trace metals leaching to groundwaters, leading to the assumption that cadmium, copper, lead, nickel, zinc, mercury, as well as phosphate, should not pose a groundwater quality threat from dredgings disposal. Subject to complexation with organic matter, site conditions and solids transformation, manganese and iron may impact underlying groundwater. Chloride, sodium and potassium can possibly affect groundwater quality, depending upon dilution capacity and ion exchange potential. Total organic carbon (with possible mobilization of trace metals) and alkalinity may increase with leachate migration.

As dredged material remains undisturbed over the long-term, total organic carbon and orthophosphate may be released to drainage waters.

Odor generation from exposed in-lake sediments and from excavation, hauling and disposal operations may occur, depending upon various physical/meteorological factors and temperature fluctuation.

The present aquatic ecosystem and benthic habitat of Forest Lake would be eliminated and, upon refilling, be reestablished with a modified, and possibly, more diversified community.

Exhaust, dust and noise generation would be anticipated along access roads between the dredging site and the disposal area due to increased truck traffic. Noise from operation of dredging and transport equipment will be a temporary impact on the residential development around the impoundment, but will be minor at the disposal site due to present earth-moving equipment activity.

The propagation of mosquitoes or other insect vectors is possible upon inadequate drainage of the containment area.

Adverse impacts upon wildlife habitat in the vicinity of the dredging and disposal areas would be minimal over both short- and long-term periods, due to the nature of the proposed work and present abutting land use.

D. Comparative environmental assessment of alternatives

Based upon an environmental evaluation system model for water resources projects developed in 1973, a comparative assessment of alternatives in TABLE 18 utilizes a ranking system of four major information categories with nineteen major components. This evaluative method is merely a tool providing a basis for alternatives comparison and should not be construed as a definitive measure of the magnitude or extent of anticipated environmental impacts. Component rankings for each environmental category are predetermined as to their relative significance in a project of this nature. Subsequent ranking values for each alternative and category are estimated, where 0.0 indicates the worst and 1.0 indicates the best environmental conditions. The products of the component and alternative ranking values are summed to give a relative magnitude of environmental impact of the alternatives for each environmental category and total environmental impacts.

The results of the comparative environmental assessment methodology for Lake-wide rehabilitation alternatives indicates mechanical dredging to be the most environmentally-acceptable approach, with mechanical raking the most acceptable short-term approach. "No action" is by far the least desirable option from a general environmental viewpoint, with cutting/harvesting having an intermediate ranking.

TABLE 18

FOREST LAKE STUDY
COMPARATIVE ENVIRONMENTAL ASSESSMENT OF ALTERNATIVES

Component Ranking	Environmental Component	"No Action" Approach		Cutting/ Harvesting		Mechanical Raking		Mechanical Dredging	
	Physical/Chemical								
8	Biochemical Water Quality	0.0	0.0	0.1	0.8	0.3	2.4	1.0	8.0
6	Chemical Water Quality	0.0	0.0	0.1	0.6	0.8	4.8	1.0	6.0
6	Physical Water Environment	0.0	0.0	0.2	1.2	0.5	3.0	1.0	6.0
8	Land Use	0.0	0.0	0.4	3.2	0.6	4.8	1.0	8.0
4	Air Quality	0.9	3.6	1.0	4.0	0.4	1.6	0.0	0.0
2	Noise Pollution	1.0	2.0	0.7	1.4	0.8	1.6	0.0	0.0
34			5.6		11.2		18.2		28.0
	Ecology								
6	Terrestrial Species and Populations	0.0	0.0	0.1	0.6	0.7	4.2	1.0	6.0
6	Terrestrial Habitats and Communities	0.0	0.0	0.8	4.8	0.9	5.4	1.0	6.0
6	Aquatic Species and Populations	0.2	1.2	1.0	6.0	0.1	0.6	0.0	0.0
6	Aquatic Habitats and Communities	0.0	0.0	0.1	0.6	0.3	1.8	1.0	6.0
24			1.2		12.0		12.0		18.0

TABLE 18 (cont'd)

FOREST LAKE STUDY
COMPARATIVE ENVIRONMENTAL ASSESSMENT OF ALTERNATIVES

Component Ranking	Environmental Component	"No Action" Approach		Cutting/ Harvesting		Mechanical Ranking		Mechanical Dredging	
	Aesthetics								
6	Water	0.0	0.0	0.2	1.2	0.5	3.0	1.0	6.0
5	Biota	0.0	0.0	0.2	1.0	0.4	2.0	1.0	5.0
3	Air	1.0	3.0	0.6	1.8	0.2	0.6	0.0	0.0
4	Land	0.1	0.4	0.0	0.0	0.7	2.8	1.0	4.0
4	Structures	1.0	4.0	0.9	3.6	0.8	3.2	0.0	0.0
2	Composition/ Compatability	0.0	0.0	0.9	1.8	1.0	2.0	0.7	1.4
24			7.4		9.4		13.6		16.4
	Social								
7	Community Well-being	0.0	0.0	0.1	0.7	0.8	5.6	1.0	7.0
6	Health and Safety	0.0	0.0	0.3	1.8	1.0	6.0	0.8	4.8
5	Environmental Interests	0.1	0.5	1.0	5.0	0.4	2.0	0.0	0.0
18			0.5		7.5		13.6		11.8
100	TOTAL		14.7		40.1		57.4		74.2

*First column gives ranking value from 0.0 to 1.0, indicating worst to best environmental condition, respectively; second column gives composite values based upon component ranking.

NOTE: Evaluation system adopted from Dee, et al, "An Environmental Evaluation System for Water Resources Planning", 1973.

4. Public Acceptability and Implementability

Periodic cutting/harvesting of excessive macrophyte growth would not likely entail any opposition from abutters or residents of the community. Although short-term adverse impacts of this approach are minimal, remaining shallow depth, and overall continuation of recreational use limitations would not be acceptable. Furthermore, since EPA will not assist in financing a cutting/harvesting program and funding assistance by the Commonwealth through its lakes program cannot be assumed indefinitely, the Town or affected residents would eventually be required to assume the total cost for continuation of the program. Similar attitudes would likely be inherent for mechanical raking.

Dredging would raise some concern from local residents due to generated odors, noise, dust and exhaust emissions attributable to dredging and disposal operations, short-term safety hazard potential, as well as short-term limitations on Lake usage. However, the short-term social impacts are outweighed by the aesthetic and recreational benefits of implementing such a long-term rehabilitation effort. The major constraint to the acceptability and implementability of dredging portions of Forest Lake is its economic burden. Although EPA would conceivably finance 50 percent of the costs for implementing a dredging program, a substantial cost would still be incurred by both the project proponent.

5. Comparative Assessment of Alternatives

The overall evaluation of technical, economic, environmental and implementability criteria for cutting/harvesting, mechanical raking and mechanical dredging options leads to a comparison of these alternatives in terms of their anticipated cost-effectiveness. The dollar costs associated with technically simple periodic programs are substantially lower than those for implementing dredging approaches. However, such easily implemented alternatives would, in themselves, have short-term, questionable success in improving Forest Lake for diversified recreational use.

Dredging of nutrient-rich bottom sediments from the shallow zones of the Lake is the most acceptable long-term water resource management approach. Mechanical dredging, following partial draining of the impoundment through modification of in-place outlet controls and constructing an outlet conduit, has been determined to be more favorable than a cutterhead-dredge pipeline transport method upon review of dredged material characteristics, disposal and productive use possibilities, as well as overall environmental and economic impacts.

6. <u>Cost/Benefit Assessment of Route 32 Borrow Pit Reclamation with Dredged Material</u>

An assessment of the anticipated costs and benefits of utilizing sediment material dredging from Forest Lake to reclaim the excavated portions of the private gravel borrow pit off Route 32 adjacent to State Fish Hatchery property is presented in consideration of environmental, technical, economic, legal and institutional concerns.

The majority of the subject site is presently being or has recently been excavated to inorganic sand/gravel deposits and, in its present state, provides poor support for vegetative reestablishment or wildlife habitat. Extensive public open space properties generally to the northeast and south of the site under the jurisdiction of the Massachusetts Division of Fisheries & Wildlife and the Town of Palmer provide conservation, as well as recreation opportunities. The provision of an organic substrate capable of supporting vegetation through the placement of dredged sediments may effectively extend this largely forested or wetland area and provide greater ecological diversity than presently exists on the site.

Placement of dredged material at the gravel borrow pit is not expected to influence any substantial changes on the ambient water quality of either groundwater or surface water resources in the area. Long-term changes on adjacent land uses are not anticipated. Significant odor generation or public health and safety impacts are not expected as a result of borrow area reclamation.

The physical properties of in-place sediments negate their utilization as a workable material in any structural use, but are conducive to mixture with inorganic material (sand/gravel) to create a suitable soil cover material. Vegetative stabilization of the exhausted borrow pit would minimize erosion from the excavated site and subsequent sedimentation in the stream draining toward the State Fish Hatchery reservoir. Scarification by discing or harrowing along the ground contour or tracking from tractor cleats would facilitate seedling emergence, reduce the velocity of rainfall runoff and increase the infiltration of water to seedbed depth.

The site would provide sufficient disposal capacity for dredged material. Site size and configuration would not adversely impact possible open space use or recreational development.

Estimation of the actual market value of dredged material is difficult, due to uncertainty of particular targeted uses, transport modes and potential variability of private contractor's bid values. However, MDWPC recently reported in a feasibility study for another pond resource that dewatered dredgings may be marketed at about $1.00/yd^3.

The acquisition of pertinent permits and environmental clearances on local, Commonwealth and Federal levels prior to dredging/reclamation project initiation will ensure conformance with regulatory requirements.

Property ownership transfer or obtaining easements may be required since both the dredged material disposal/reclamation site is privately-owned. Neither the proposed project, nor projected disposal site use, should contradict local land use restrictions.

SECTION V

RECOMMENDED RESTORATION PROGRAM

SECTION V

RECOMMENDED RESTORATION PROGRAM

1. Recommended Watershed Management Measures

The recommendation of implementable watershed management measures to improve long-term water quality and physical conditions is presented herein.

The placement of an estimated 400 square yards of stone rip-rap or gabions along approximately 800 linear feet of shore abutting River and Bennett Streets along the main basin is recommended. In conjunction with vegetative stabilization and/or mulching above the riprap, this would serve to reduce the continuing erosion of the sandy-gravel embankment through wind/wave action, stormwater runoff and informal access by fishermen. Provision of several railroad-tie access stairways along the slope would reduce future bank erosion. Anticipated construction of such stabilization work would require one or more of the regulatory approvals described in SECTION III.

Modification of the existing storm drainage facilities are recommended to minimize runoff-related nutrient and sediment loadings to the northern end of the main basin. A closed drainage system consisting of eight (8) catch basins and an estimated 1,600 linear feet of 12 and 36 inch diameter rein-forced concrete and/or corrugated metal pipe with appropriate berming would serve to eliminate a) the 12 inch diameter direct-inlet pipe draining the southerly side of Bennett Street to the northeasterly cove; b) the two paved swales along the southerly side of Bennett Street along the beach area; c) drainage from River Street entering via paved swale at the northwesterly cove; and d) indirect runoff presently causing minor slope erosion and pavement failure along the causeway between major and minor basins. This drainage system would outlet to the minor basin adjacent to the present equalizing culvert.

Route 32 pavement stormwater drainage reportedly adversely impacts the State Fish Hatchery operations due to elevated levels of chlorides and suspended solids. The Massachusetts Department of Public Works, in developing plans for upgrading/realigning the highway, should consider diverting such drain-age from fishery facilities.

Non-point source pollutant controls, implementable on a local level and applicable to Forest Lake, include the following:

1. Promote non-phosphorus detergent use for dwellings situated within 300 linear feet of the shoreline;

2. Control lawn fertilizer use on shoreline properties and minimize leaf deposition in the Lake through establishment of coniferous trees;

3. Establish erosion control practices at construction sites within the watershed and maximize efficiency of existing stormwater collection facilities through maintenance and/or improvement of sedimentation capacity; and,

4. Implement on-site wastewater disposal system management through periodic maintenance of systems, inspection by the Board of Health, as well as enforcement of local and Commonwealth requirements for new system siting and their maintenance within the watershed.

2. Recommended Short-Term In-Lake Management

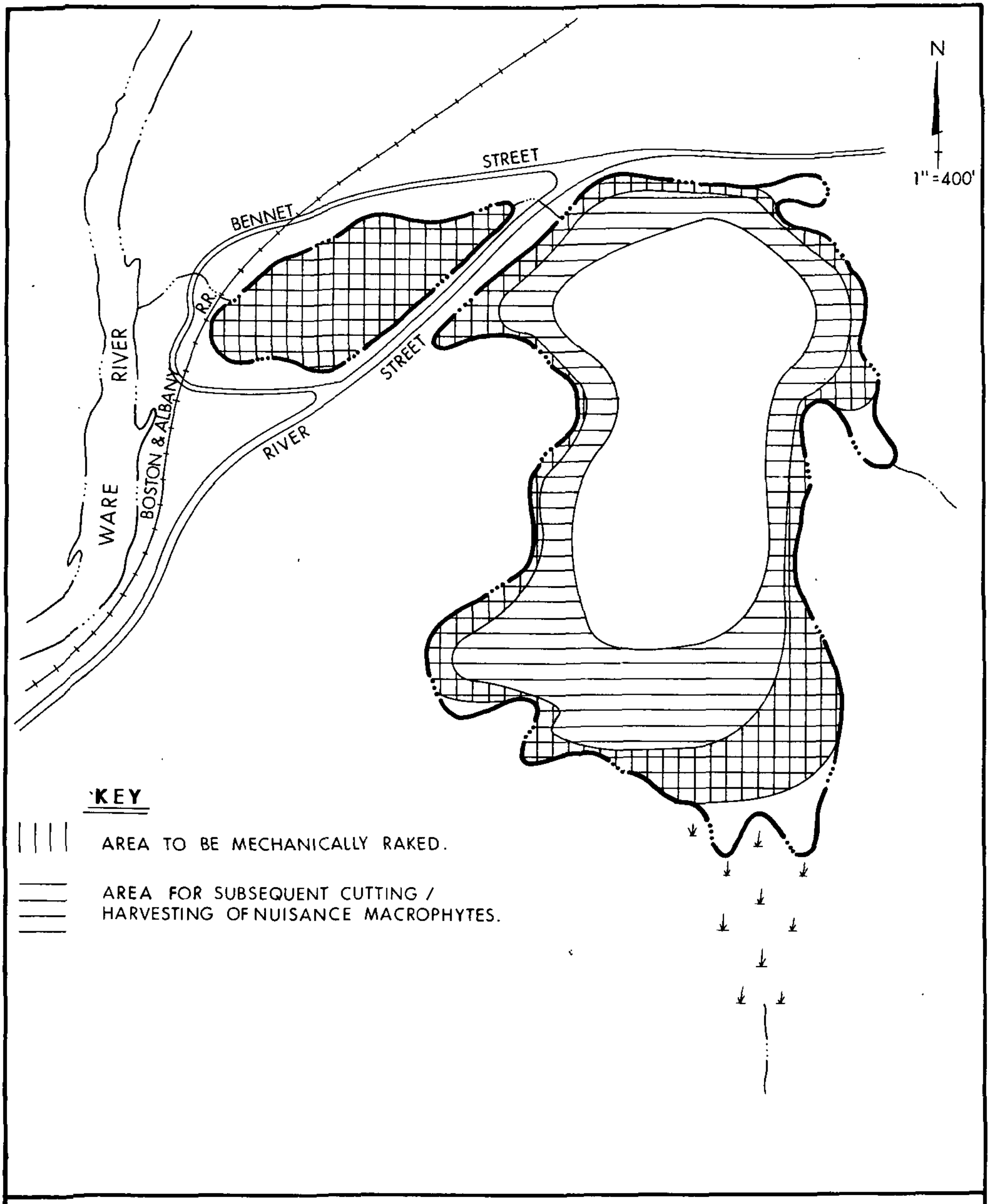
The recommended short-term in-lake management approach involves initial use of a mechanical rake apparatus to remove nuisance macrophytes, their root structure and up to two (2) feet of bottom sediment in a 24-acre portion of the main basin (shown on FIGURE 7) and the entire six-acre minor basin. As necessary, subsequent cutting/harvesting of nuisance macrophytes is recommended to check growth of reestablished weeds.

Up to 75,000 cubic yards of removed material may be generated through this approach. Proposed handling and disposal methods are discussed under the long-term management approach.

An estimated 40 days would be initially required to mechanically-rake the proposed area, while subsequent weed harvesting using a CHUB harvester would take up to 25 days.

3. Recommended Long-Term In-Lake Management

The removal from Forest Lake's bottom of an estimated 450,000 cubic yards of sediment material, which presently accelerates nuisance aquatic weed growth and causes extreme shallowness in portions of both major and minor basins, in conjunction with drawdown of the water level is recommended for long-term rehabilitation. The most feasible means of removing the sediment material from the Lake, upon evaluation of technical, economic, environmental and implementability criteria, is to drain the Lake through construction of permanent outlet con-



SHORT - TERM RESTORATION APPROACH

FOREST LAKE — PALMER, MASSACHUSETTS

FIGURE 7

trol works (and provision of drawdown pumping capacity) and excavate the material by dragline equipment, other specialized dredging apparatus and/or conventional earth-moving equipment. Excavated material would be transported by truck haul along present access routes to the private gravel borrow area on Route 32 adjacent to State Fish Hatchery property for admixture with on-site sand/gravel material, proper grading and vegetative stabilization.

FIGURE 8 depicts proposed bathymetric mapping and area to be dredged, assuming dredging to apparent sandy-gravel hard bottom in some shoreline areas with dredging to elevations below which light can adequately support plant growth for much of the impoundment. The physical removal of nutrient-rich sediments and plant biomass through weed harvesting practices will diminish in-pond nitrogen and phosphorus loadings, which contribute to nuisance aquatic macrophyte growth and eliminate a most suitable substratum for rooted aquatic weeds. Impoundment deepening to a relatively firm, inorganic layer will make the establishment of most types of aquatic weeds difficult and reduce the potential for increased microscopic or floating algal growth.

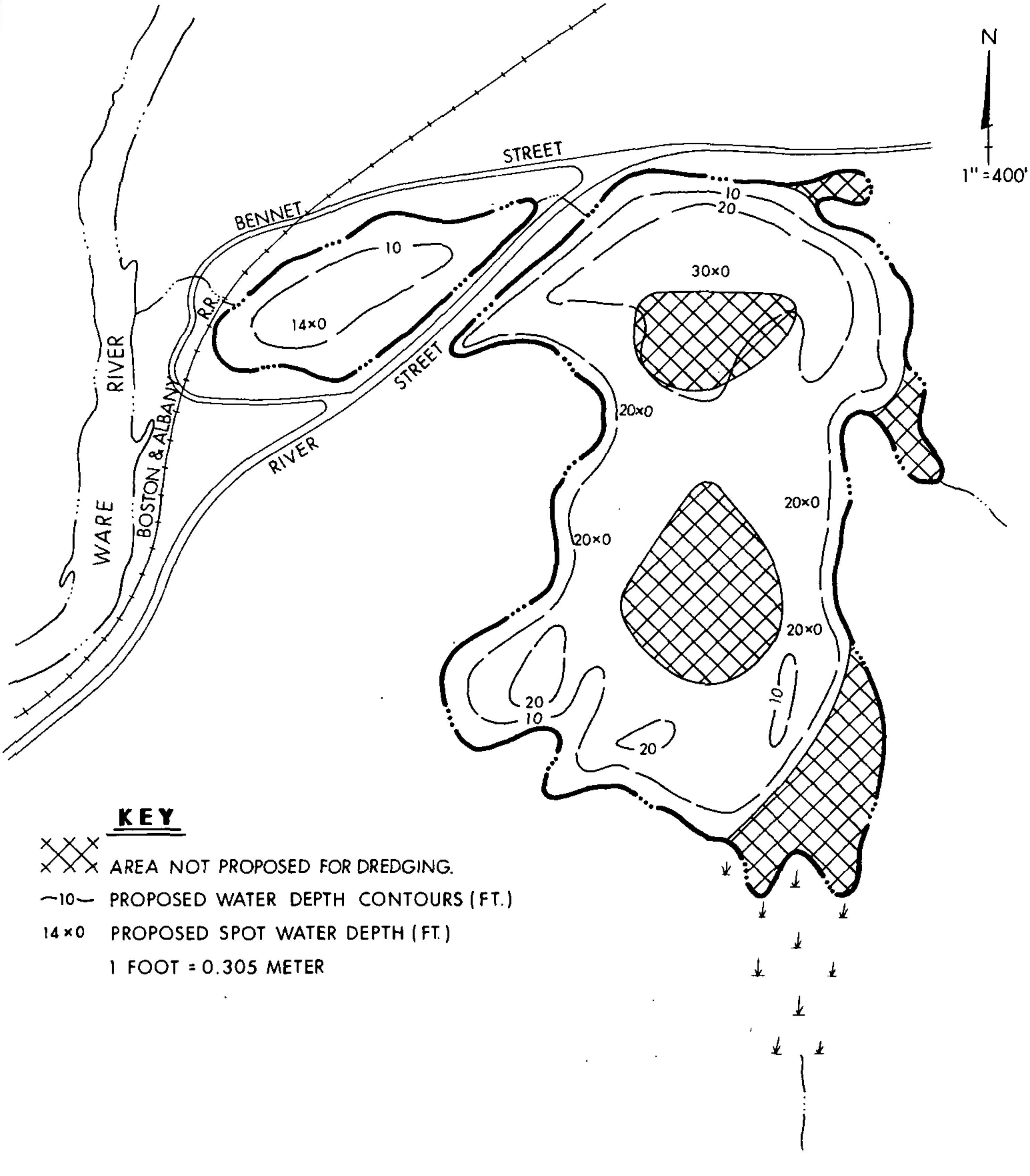
The dredging of sediment material along the entire shoreline and across the surface area of Forest Lake is constrained by shoreline configuration, equipment reach limitations, access limitations and economics. However, upon overwinter drawdown, fine-grained sediment consolidation and macrophyte freezing may somewhat improve portions not dredged. Furthermore, a continuing program of partial overwinter drawdown to expose shallow areas susceptible to weed growth may be instituded upon construction of a permanent level control structure.

4. Estimated Costs

Estimated costs for both long- and short-term restoration measures are summarized in TABLE 19.

Estimated costs presented herein are preliminary and are intended to provide a general range for comparison and planning purposes. More detailed, up-to-date estimates would be required in final design of outlet controls or layout of the dredging project. The cost estimates are based upon the best available information regarding current construction costs (ENR CCI = 3600) and particular conditions in the project area.

Estimated rehabilitation costs include allowances for equipment mobilization/operation, truck haul, site preparation, materials grading and stabilization, erosion/siltation controls and drainage improvements. Costs have not been pro-



LONG - TERM RESTORATION APPROACH

FOREST LAKE — PALMER, MASSACHUSETTS

FIGURE 8

TABLE 19

FOREST LAKE STUDY

RECOMMENDED RESTORATION PROGRAM COST SUMMARY

Short-Term	
Initial mechanical rake treatment (30 acres)	$ 37,900
Current cost of cutting/harvesting	5,300/yr
Long-Term	
Bennett & River Streets storm drainage improvements*	53,800
Shoreline stabilization*	23,100
Outlet control conduit*	31,600
Dredging operations (30 acres)	1,150,000
Material hauling	1,300,000
Disposal site preparation/grading*	$ 385,000
TOTAL	$2,943,500

*includes 15% allowance for engineering and administration.

jected for facilities development on the disposal/reclamation site nor possible further improvements to Forest Lake, including access or beach improvements and stocking activities. Contractors' overhead and profit have been included in cost estimates presented.

An allowance of ten percent has been added to construction costs for contingency conditions for unforeseen problems. Additional costs for engineering, surveys and legal/administrative overhead have been estimated at 15 percent of the estimated project cost.

5. Project Implementation and Funding Schedule

Drawdown and dredging or mechanical raking should be scheduled so as to 1) minimize adverse environmental impacts on in-Lake and downstream aquatic species and associated terrestrial wildlife, 2) minimize potential for odor generation, 3) maximize capacity for natural dewatering and stabilization of exposed sediments, 4) minimize project duration and 5) maximize capacity for impoundment refill during spring rains and snowmelt conditions.

An estimated 100 weeks would be required for operation of four (4) 1½ cubic yard capacity bucket dredges to remove 300,000 cubic yards of sediment; while 75 weeks would be required in using two (2) Sauerman dredges to remove 150,000 cubic yards not adjacent to the shore.

Spawning periods for freshwater fish species vary, but autumn generally marks the principal spawning time (September to November for brook and brown trout).

The lowest relative humidities and temperatures prevail during the months from November to March, indicating this time period to be best suited for odor minimization and sediment densification. Drawdown should be initiated in consideration of the possibility of high November rainfall, which may hinder dredging operations mobilization. Winter snowfall should be removed only as necessary to permit sediment excavation, with scheduling to prevent excessive frost penetration, which may inhibit dredging efficiency during winter months.

Assuming funding appropriation of 50 percent of the total long-term dredging/reclamation project cost by EPA through the Section 314 lakes program, in addition to 50:50 joint financing of the remainder by the Commonwealth (through

DEQE's Eutrophication and Aquatic Vegetation Control Program and/or other programs of the Division of Water Pollution Control and Division of Waterways) and on the local level the following funding schedule results:

	Total Cost	EPA Section 314 Appropriation	Massachusetts DEQE Share	Local Share
Long-term restoration	$2,943,500	$1,471,750	$735,875	$735,875
Mechanical rake/cutting-harvesting	$ 37,900	---	$ 28,425	$ 9,475
	+$5,300/yr	---	+$3,975/yr	+$1,325/yr

Cutting/harvesting is assumed to be non-fundable by EPA and initially 75 percent financed by DEQE for the purposes of this schedule. Local labor and equipment resources may serve to offset dollar appropriations.

The recommended mechanical rake/cutting/harvesting program may be reduced in accordance with available local and/or DEQE funds.

SECTION VI

PUBLIC PARTICIPATION SUMMARY

SECTION VI

PUBLIC PARTICIPATION SUMMARY

1. General

A significant effort was made by CULLINAN ENGINEERING CO., INC., throughout the duration of the Forest Lake Feasibility Study to keep interested Palmer residents and other concerned citizens informed. Public meetings were held on September 3, 1980, and November 13, 1981; additional informal public meetings with the Forest Lake Action Group (FLAG) were held on December 3, 1980 and July 13, 1981.

Arrangements for the meetings were handled by FLAG. Special thanks is extended to Mr. Bernie Griffin, President of FLAG, for his involvement in the scheduling, advertising and chairing of the meetings.

A summary of each of the four (4) public meetings follows. Copies of attendance lists, handouts or other related items are included at the end of this section for the readers' reference.

2. September 3, 1980 Public Meeting

An initial public meeting was held at the Forest Lake Pavilion to announce that the Forest Lake Feasibility Study was officially underway. Richard M. Cox, representing Cullinan Engineering Co., Inc., reviewed the contracted scope of work to be completed by CULLINAN for the Massachusetts Division of Waterways during the nine-month project period.

Concern was expressed by several members of the audience that the completed study should comply with current State and Federal regulations to allow for the possibility of applying for and receiving future implementation monies. Mr. Cox pointed out that the existing contract would have to be amended to allow for additional water quality sampling. He agreed to attempt to contact the Division of Waterways to amend the contract.

An attendance list was circulated (copy follows). A total of twenty-three (23) individuals were present including several members of FLAG and a representative from Senator Wetmore's office. Handout materials (copies follow) were distributed by CULLINAN which described the Feasibility Study's scope of work and the Environmental Protection Agency's Section 314 Clean Lakes Program.

3. <u>December 3, 1980 Public Meeting</u>

An informal meeting was held with five members of FLAG, newly-elected State Representative Moriarity and a representative from Senator Wetmore's office to review study progress to date. Richard Cox represented CULLINAN.

Mr. Cox reported that a verbal committment had been received from Mr. Mario Boschetti, Massachusetts Division of Waterways, that an amendment to the Forest Lake Feasibility Study contract had been approved. Additional funds have been authorized and the study period extended to allow for additional water quality sampling throughout the summer of 1981. The new project completion date was set for October 1981.

Handout materials were distributed by Mr. Cox which summarized the overall water quality sampling schedule and reported preliminary analyses results.

It was agreed to meet next in the spring or early summer to review study results.

4. <u>July 13, 1981 Public Meeting</u>

Seven (7) members of FLAG were present to review with Mr. Cox of CULLINAN progress on the Forest Lake Feasibility Study. Several large mounted maps/displays were used by CULLINAN to indicate the location of water quality sampling stations, Forest Lake's watershed, water depths and the extent of sediment deposits in Forest Lake and aquatic vegetation presence as of June 1981.

The problem with existing sediments was discussed in detail. Mr. Cox stated that approximately one million cubic yards of sediment are believed to be present in Forest Lake. Removal costs are estimated to be around $2.00 per cubic yard. The possible use of local contractors to remove the sediments was discussed.

Mr. Cox reviewed the water quality sampling program which has been completed to date and explained that the sampling program would be finalized in August. A public meeting will be scheduled in September or October to review the findings, conclusions and recommendations contained within the Forest Lake Feasibility Study Report.

5. <u>November 6, 1981 Public Meeting</u>

A public information meeting sponsored by the Forest Lake Action Group (FLAG) was held on November 6, 1981, at 7:00 PM at the Palmer Town Hall in Palmer, Massachusetts. The meeting was initiated by Mr. Bernie Griffin, President of FLAG. Mr. Griffin introduced Mr. Richard Cox and Mr. Mark Popham, representatives of Cullinan Engineering Co., Inc., to review the results of the year- long Forest Lake Feasibility Study.

Mr. Cox distributed a handout (copy follows) to all in attendance prior to speaking. An attendance list was also circulated (copy follows). Referring to the handout and several large mounted maps of Forest Lake and its watershed, Mr. Cox reviewed the field work tasks completed by CULLINAN personnel during the previous one-year period.

Mr. Popham reviewed the findings of CULLINAN and explained feasible water quality improvement alternatives.

Two (2) recommended approaches were presented:

1. Short-term - utilization of a mechanical rake to remove weeds, weed roots and some bottom sediments from approximately 24 acres of the main basin of Forest Lake and the entire minor basin. Estimated cost was $33,000.

2. Long-term - Implementation of limited mechanical dredging program to remove approximately 350,000 cubic yards. Estimated cost was 1.4 million dollars. Reuse of material as a sanitary landfill cover material was discussed.

Mr. Cox reviewed possible funding sources and anticipated local funding requirements. EPA's 314 program was reviewed as was DEQE's Eutrophication program.

Several questions, comments and responses followed:

1. Reasons were given for why CULLINAN ruled out herbicide treatment.

2. Difference between using the mechanical rake and the weed harvester were discussed. CULLINAN recommends the rake despite its higher cost.

3. Steps required to free up remaining $14,700 of the initially appropriated $30,000 were discussed. Representative Moriarty will see what he can do to insure that Palmer can spend the money on the mechanical weed harvester.

4. CULLINAN emphasized that the primary water quality problem with Forest Lake is in its sediments. In-flowing tributaries do not contain excessive quantities of nutrients.

CULLINAN agreed to send Bernie Griffin several copies of the draft report by the end of November. No further meeting with FLAG is necessary. Perhaps a meeting with Division of Waterways will be necessary to review the report's recommendations.

Meeting adjourned at 9:00 PM.

THE GENERAL COURT OF MASSACHUSETTS
State Senate
Committee on Ways and Means
STATE HOUSE, BOSTON 02133

HON. ROBERT D. WETMORE
WORCESTER, FRANKLIN, HAMPDEN
AND HAMPSHIRE DISTRICT
ROOM 409
TEL. 727-1540

OTHER COMMITTEES:
CHAIRMAN:
COMMERCE AND LABOR
MEMBER:
SENATE WAYS AND MEANS
NATURAL RESOURCES AND AGRICULTURE
LOCAL AFFAIRS

August 22, 1980

Bernie Griffin, President
Forest Lake Action Group
27 Pleasant Street
Bondsville, Mass. 01009

Dear Bernie,

I am writing to bring you up to date on the current status of the eutrophication study of Forest Lake.

I have contacted both the Division of Waterways and Cullinan Engineering on your behalf. I was informed that Cullinan has received the necessary contracts and is anxious to schedule an informational meeting in Palmer on either September second or third to explain the scope of the study. If you would provide me with the most convenient place and time for you for the meeting, I will be happy to contact Cullinan on your behalf to arrange the meeting.

I am happy to be of service. If I can be of further assistance in the future on this or any other matter, please feel free to call on me.

Sincerely,

ROBERT D. WETMORE
Senator

RDW:mcv

cc: Board of Selectmen

CULLINAN ENGINEERING CO., INC.

P. O. BOX 191 / 200 AUBURN STREET, AUBURN, MASSACHUSETTS 01501 / (617) 832-5811
25 HUNTINGTON AVENUE, BOSTON, MASSACHUSETTS 02116 / (617) 536-3040

September 5, 1980 *CIVIL ENGINEERS – LAND SURVEYORS*

Mr. Bernie Griffin, President
Forest Lake Action Group
27 Pleasant Street
Bondsville, Massachusetts 01009

Subject: Forest Lake Diagnostic/Feasibility Study
CEC Job No. 3490

Dear Bernie:

Thank you for the excellent job you did in setting up and chairing the September 3, 1980, informational meeting on the above subject project. We were pleased with the turnout and were impressed by the local interest exhibited.

Enclosed for your information is a copy of the attendance list that was circulated.

We will plan to meet with your group sometime towards the end of November to review our progress. Hopefully, the water quality sampling schedule will be resolved prior to that time.

Please contact me directly if you have any questions, or desire additional information.

Very truly yours,

Richard M. Cox

Richard M. Cox, PE
Project Engineer

RMC/pcs

Enclosure

C: Senator Robert D. Wetmore

Mario M. Boschetti,
Environmental Engineer

Forest Lake
9-3-80

Attendance List

1. Rick Cox	Cullinan Engineering	Auburn MA
Bernard Griffin	FLAG	Bondsville MA
Del P. Virgilio	Virgilio Construction Co	Pittsfield Ma
Joe Lemanski.		Bondsville Ma.
Stanley J. [illegible]		Thorndike Mass
Joseph [illegible] Salamon	FLAG	Thorndike MASS
Christy B. Salamon		THORNDIKE MASS
Joseph Kologey	340 Main St.	Monson
Thomas Kologey	Bridge St.	Monson Mass.
Roland O'Conato	Forest Lake Resort	Forest Lake Resort
Shirley Gerrish		Bondsville Mas.
Omer [illegible]	all Volunteers [illegible]	[illegible]
William [illegible]	FOREST LAKE	PALMER MASS
Edward R. Lebera	1586 Ware St.	Palmer Ma
James [illegible]	Bennett St.	Palmer mass.
Joseph [illegible]	Ware St	Palmer Mass
SID MACRAE	41 HIGHLAND ST.	MEDWAY, MASS
Ted Yargeau Jr.	Forest Lake	Palmer Mass.
Randy Hebert	Forest Lake	Palmer
Bill Moriarty	FLAG	Ware
Fred [illegible]		[illegible] Mass.
Mr & Mrs John Sieczkowski	Forest Lake	Palmer, Ma.
Steve Brewer	Senator Wetmore's Office	Barre

DIAGNOSTIC/FEASIBILITY STUDY
FOREST LAKE
PALMER, MASSACHUSETTS

FOR

COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING
DIVISION OF WATERWAYS

-SCOPE OF WORK-

1. REVIEW AVAILABLE DATA

2. FIELD INVESTIGATIONS

   .Water Quality Sampling and Analysis
   .Pollution Sources
   .Watershed Characteristics
   .Biological Resources

3. SEDIMENT INVESTIGATIONS

4. ANALYSIS OF ALTERNATIVES

5. CONSULTATION WITH STATE AND TOWN OFFICIALS

6. FINAL REPORT

   .Summary of Existing Conditions, Findings and Recommendations
   .Description of Data Reviewed and Investigations Completed
   .Analysis/Evaluation Methods, Assumptions and Information Sources
   .Short-Term and Long-Term Alternative Approaches Considered
   .Recommended Approach, Estimated Costs and Implementation Steps

BY

CULLINAN ENGINEERING CO., INC.
CIVIL ENGINEERS/ENVIRONMENTAL CONSULTANTS/LAND SURVEYORS
AUBURN, MASSACHUSETTS BOSTON, MASSACHUSETTS

DIAGNOSTIC/FEASIBILITY STUDY
FOREST LAKE
PALMER, MASSACHUSETTS

SCOPE OF CONSULTANT'S WORK

A. General

1. To study the present status and causes of eutrophication at Forest Lake in Palmer.

2. Investigate and evaluate sources of pollution to Forest Lake and its watershed area, including all tributaries, surface drains and sub-surface disposal systems.

3. Evaluate the impact of nutrients, such as phosphates and nitrates on the water quality and eutrophication status of Forest Lake.

4. Conduct nutrient and hydrologic budgets of Forest Lake.

5. Conduct borings in Forest Lake in at least six locations to determine the depths and composition of sediment on the bottom of Forest Lake.

6. Identify aquatic vegetation and distribution in Forest Lake.

7. Insofar as the Scope of Consultant's Work allows, the study shall fulfill the requirements of the diagnostic-feasibility studies under Sec. 314 of the Federal Clean Lakes Program and the Final Application under the Massachusetts Eutrophication and Aquatic Vegetation Control Program.

B. Review of Available Data

A detailed review will be made of all available data including, but not limited to, the following as applicable:

1. Town and regional plans;

2. Previous biological, engineering and planning reports and studies;

3. Applicable Town, State and Federal regulations; and

4. Geological, soils, water resources, environmental reports and surveys.

C. Field Investigations

Field investigations will be carried out as necessary to supplement and verify available data, to determine conditions, to establish planning and engineering criteria and to determine characteristics of the site.

D. Sediment Investigations

A sampling program will be conducted to determine the potential environmental and public health impacts and suitability of sediments for the disposal or use alternatives studied.

1. Collection of sediment core samples to assess both horizontal and vertical variations;

2. Toxic substance analysis to include arsenic, copper, lead, mercury, barium, cadmium and chromium;

3. Physical analysis to include pH, percent organic matter, odor, grain size; and

4. Develop dredging costs including disposal of dredged material.

E. Consultation with State and Town Officials

Officials of the Town, Forest Lake Improvement Association, the State Division of Water Pollution Control, the Division of Fisheries and Wildlife and the Division of Waterways will be contacted as necessary during the preparation of the report. The Consultant will attend meetings as requested by the Department or deemed necessary during the preparation of the report.

F. Analysis

Available data and that collected during field and laboratory investigations will be compiled and analyzed. Included in the analysis will be cost estimates of the various alternatives investigated.

G. Report

A written report will be submitted setting forth the findings of the investigations and analysis. The report will include the following:

1. Summary of existing conditions, findings and recommendations;

2. Description of data reviewed and investigations carried out;

3. Description of analysis methods used, assumptions, sources, criteria and all other information and processes used in arriving at final conclusions and recommendations;

4. Recommendations and various alternative approaches developed during the preparation of the report;

5. Summary of estimated costs for the recommended approach and alternatives; and

6. The report shall include both short-term and long-term restoration programs and alternative methods which are both feasible and practicable.

U.S. ENVIRONMENTAL PROTECTION AGENCY
CLEAN WATER ACT - SECTION 314
"THE CLEAN LAKES PROGRAM"

COOPERATIVE AGREEMENTS FOR PROTECTING AND RESTORING PUBLICLY OWNED FRESHWATER LAKES

Regulations Initially Proposed - 1/29/79
Final Regulations Effectuated - 2/5/80

FUNDING REQUIREMENTS

° Availability of Public Access
° Massachusetts Division of Water Pollution Control Applies for the Municipality
° State Certification of Project Consistancy and State Priority Ranking
° Local Financial Support (30%-50% of the Project Cost)
° Non-Eligibility for Other EPA Funding (i.e. Sewerage Construction Grants Program)

TYPE OF ASSISTANCE

° Phase I Diagnositc/Feasibility Study
  Non-Federal Share - 30%
° Phase II Implementation
  Non-Federal Share - 50%

REQUIREMENTS FOR DIAGNOSTIC/FEASIBILITY STUDIES AND ENVIRONMENTAL EVALUATIONS

A. Diagnostic Study

1. Identification/Location of Lake
2. Geological Description
3. Public Access Description
4. Population/Socio-Economic Structure
5. Historical Lake Uses
6. Adverse Impacts on Lake Users
7. Other Lake Uses Within 80 KM
8. Point Sources
9. Watershed Land Uses
10. Historical/Current Limnological Data
11. Biological Resources

B. Feasibility Study

1. Identification/Discussion of Alternatives
2. Anticipated Benefits
3. Proposed Phase II Monitoring Program
4. Proposed Milestone Work Schedule
5. Non-Federal Project Funds
6. Relationship With Other Federal Programs
7. Summary of Public Participation
8. State's Operation and Maintenance Plan
9. Permits/Permit Applications

C. Environmental Evaluation

FOREST LAKE MEETING
NOV. 6, 1981

ATTENDANCE LIST

NAME	Address	Affiliation
1. Richard Cox	Auburn, MA	CULLINAN ENGR. Co.
2. Mark W. Popham	"	"
Bernard Griffin	[illegible]	[illegible]
3. JOHN J SIECZKOWSKI SR	BENNETT ST PALMER	
4. LINDA SIECZKOWSKI	BENNETT ST	PALMER [illegible]
5. [illegible] SIECZKOWSKI	[illegible]	[illegible]
6. [illegible] Sieczkowski	Bennett St	Forest Lake [illegible]
7. [illegible]	11 King St	Palmer [illegible]
8. Julian E. Moriarty	P.O. Box 116	Ware State Rep.
9. [illegible] Hebeard	PO Box 25	Bondsville [illegible]
10. Stanley [illegible]	32 Simonich St	Chicopee [illegible]
11. R Y BROWNE III	21 Kelly St. Three Rivers, Mass.	Resident
12. Joe Kerigan Jr.	Ware St., Mass	
13. J. F. Kerrigan	Ware Rd.	Palmer, Mass
14. Bob [illegible]	[illegible] Rd	Palmer, Mass
15.		
16.		

CULLINAN ENGINEERING CO., INC.

AUBURN · BOSTON, MASSACHUSETTS

PUBLIC INFORMATION MEETING
FOREST LAKE FEASIBILITY STUDY
PALMER, MASSACHUSETTS

NOVEMBER 6, 1981

I. INTRODUCTIONS

II. SCOPE OF SERVICES

A) Forest Lake's Eutrophic Status
B) Sources of Pollution
C) Nutrient Budget & Hydrologic Budget
D) Depths/Composition of Sediments
E) Aquatic Vegetation Identification/Distribution
F) Compliance with Section 314 Requirements and DEQE's Eutrophication Program Requirements

III. PROJECT SCHEDULE

A) Division of Waterways Advertised for Consultant - November 1979
B) CULLINAN Selected as Consultant - January 1980
C) Contract Signed - August 1980
D) Duration of Field Work - September 1980 Through September 1981

IV. FIELD INVESTIGATIONS COMPLETED

A) Water Quality Sampling
   1) In-Lake Station
   2) Tributaries
   3) Stormwater Runoff
   4) Upstream/Downstream from Fish Hatchery

B) Sediments
   1) Quantity Determination
   2) Laboratory Analysis

C) Hydrologic Measurements

D) Aquatic Vegetation Identification/Distribution

CE

SECTION VII

ENVIRONMENTAL EVALUATION

SECTION VII

ENVIRONMENTAL EVALUATION

1. Displacement of People

   No recommended restorative measures shall cause any displacement of persons nor business activities.

2. Defacement of Residential Areas

   No negative visual impacts on residential areas will be realized by any proposed restorative measures. Long-term visual improvements to shoreline residents and users of Forest Lake would occur upon Bennett and River Streets slope stabilization efforts and in-lake improvements.

3. Changes in Land Use Patterns

   No significant changes in land use patterns will occur as a result of implementing any restorative measures. Future shoreline development is limited by existing land use commitments, slope constraints, wetland areas, suitable access roadways and soil conditions.

4. Impacts on Prime Agricultural Land

   No significant adverse or beneficial impacts on prime agricultural land shall accompany any proposed restorative measures. Minor beneficial agricultural impacts may occur should suitable dredged material be utilized as a soil conditioner for silage production.

5. Impacts on Park Land, Other Public Land and Scenic Resources

   Implementation of proposed restorative measures will have no adverse impacts upon any public land or scenic resources.

6. Impacts on Historic, Architectural, Archaeological or Cultural Resources

   Adverse impacts on historic or archaeological resources in the area are not anticipated. Minor basin outlet control works are believed to remain from a former grist mill at the site but would not be modified to major extent by restoration measures. Although temporary encampment by American Indians in the general area for fishing the Ware River has been reported, the presence of artifacts in Forest Lake sediments is unlikely due to the probable wetland nature of the area prior to enlargement of the Lake.

7. <u>Long Range Increases in Energy Demand</u>

Long-term watershed management and dredging measures will have no appreciable increase in energy demand. Periodic mechanical raking and/or cutting/harvesting will involve consumption of fuels for equipment operation.

8. <u>Changes in Ambient Air Quality or Noise Levels</u>

Both short- and long-term restorative measures will induce temporary nuisance air quality conditions (dust, equipment exhaust gases, odor release from disturbed sediments) and increased noise levels from equipment operation for abutting residences of the Lake and material transport routes.

9. <u>Wetlands and Floodplain Impacts</u>

Cutting/harvesting and/or mechanical raking processes will have minimal impact upon adjacent wetland resources, save for temporary wildlife disturbance through equipment operation. Impoundment dewatering and drawdown as part of dredging operations may induce temporary water table drawdown in adjacent wetland areas, while providing increased flood storage capacity in the impoundment. Control of dewatering and drawdown conduit discharges would minimize flooding in the Forest Lake outlet stream flowing to the Ware River.

10. <u>Recommended Mitigative Measures</u>

Anticipated or potential adverse impacts of proposed restoration measures may be effectively minimized by implementation of the following protective measures:

<u>Impoundment Drawdown</u>

1) Maintain outflow rate and velocity so as to prevent downstream channel scour and sedimentation;

2) Schedule and supervise drawdown so as to minimize odor generation and ensure public safety; and,

3) Implement prolonged drawdown to ensure continued integrity of shallow water supply wells of adjacent residences.

<u>Dredging and Disposal/Reclamation or Mechanical-Raking Operations</u>

1) Schedule operations so as to maximize efficiency, minimize aesthetic (noise, odors) impacts and protect affected surface waters from turbid or nutrient-carrying runoff waters;

2) Conduct truck haul of removed materials so as to minimize dust, exhaust gases, noise and odor impacts in residential areas;

3) Dispose and stabilize dredged material with suitable vegetative cover to minimize odor generation and maximize vector control;

4) Provide adequate surface and subsurface drainage to maximize natural dewatering of dredged material and implement erosion and sedimentation control practices.

5) Minimize groundwater contamination from disposal/reclamation site leachates by liming placed dredged material to minimize acidity and reduce consequent mobilization of iron and associated toxic metals (copper, chromium); grade dredgings in thin lifts to maximize plant uptake of nitrogen and consequently minimize nitrate leaching.

APPENDIX A

REFERENCES

APPENDIX A

REFERENCES

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